Chapter 4: "Image Enhancement"
Part 1 out of 3

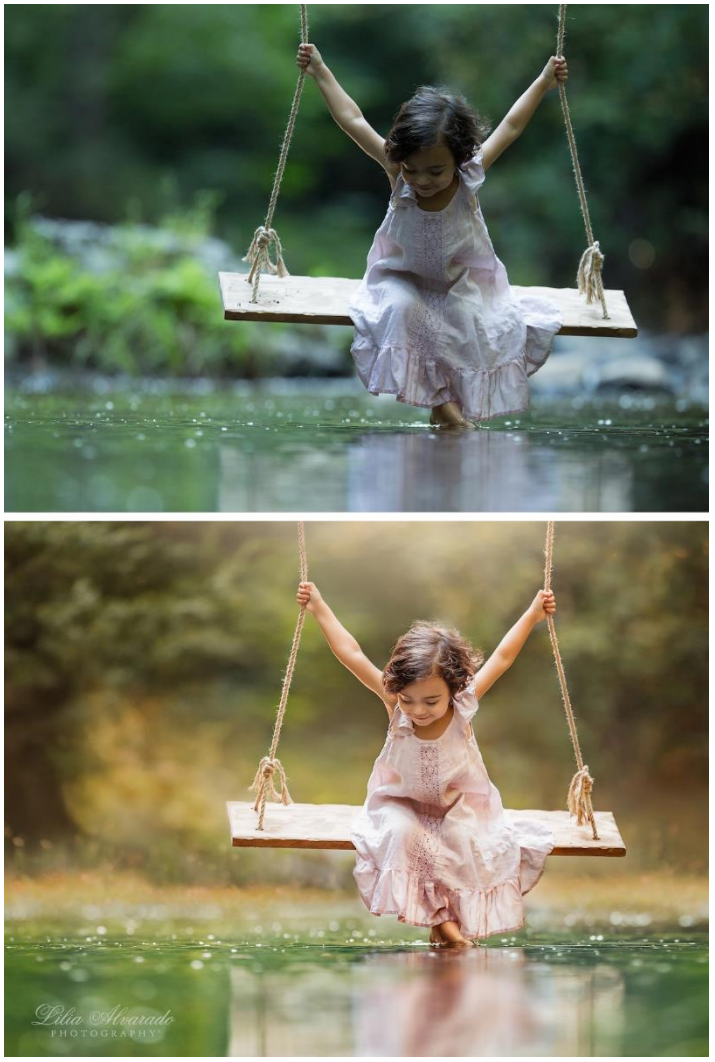
Introduction:

The goal of image enhancement procedures is to improve the visual interpretability of an image by increasing the apparent distinction between features in the scene.

Chapter 4: "Image Enhancement"

Introduction: *(continue)*

- Enhancement operations are normally applied to image data after it has been rectified & the appropriate restoration procedures have been performed.
- They can be categorized as; contrast manipulations, spatial feature manipulations, or multi-image manipulations.

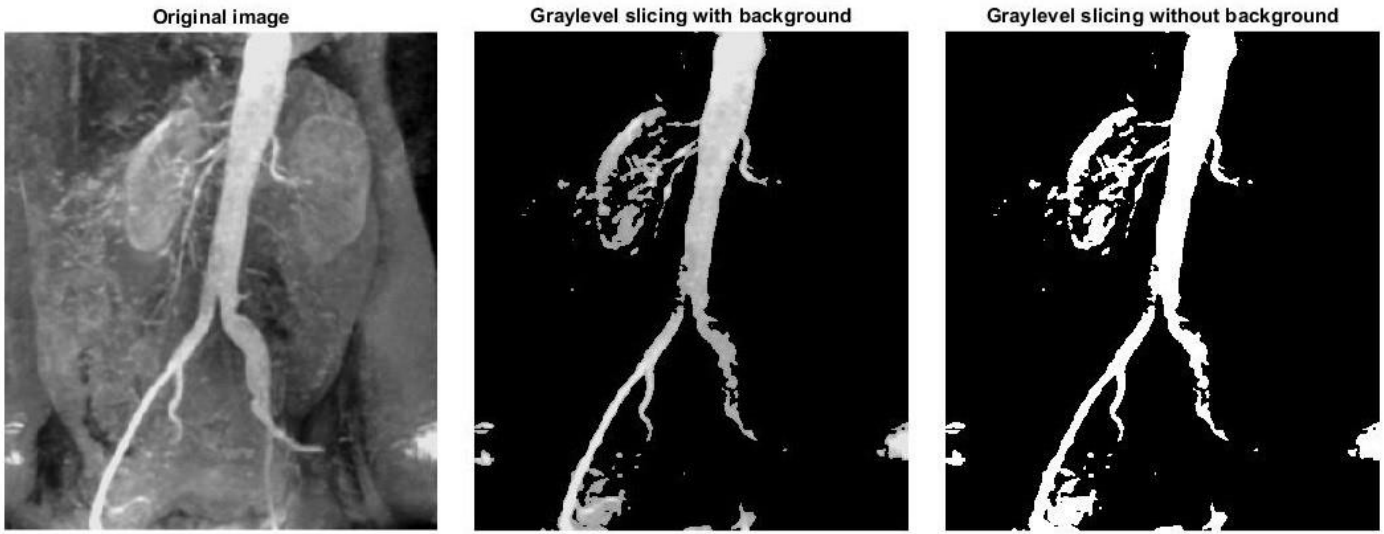


Chapter 4: "Image Enhancement"

Contrast Manipulations:

There are many forms of contrast manipulations; however, we will cover only three of them her;

- **the gray-level thresholding,**
- **level slicing, &**
- **contrast stretching.**

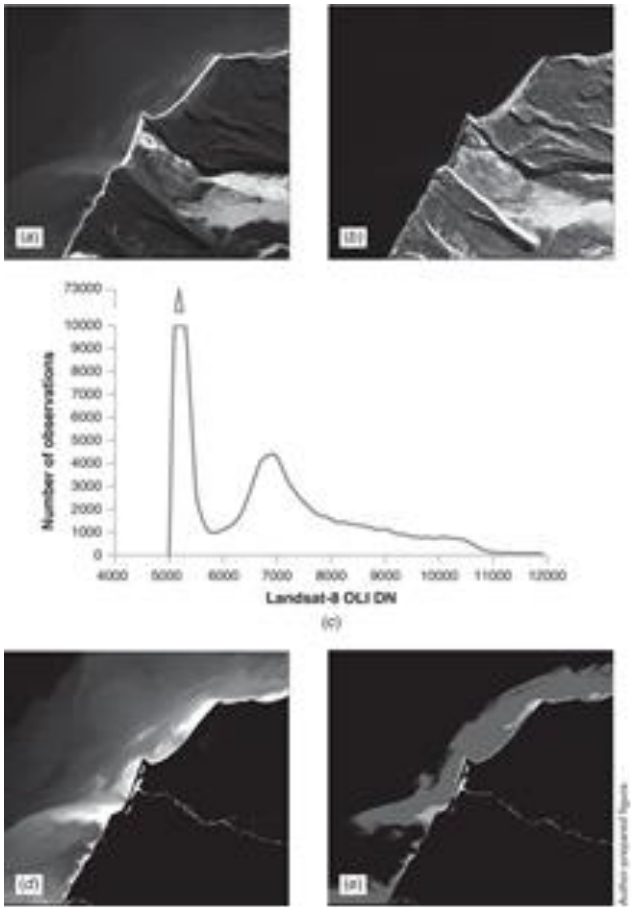


Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

1. **Gray-level thresholding:**

   This procedure is used to segment an input image into two image; one for those pixels having values below an analyst-defined gray level & one for those above this gray level value.

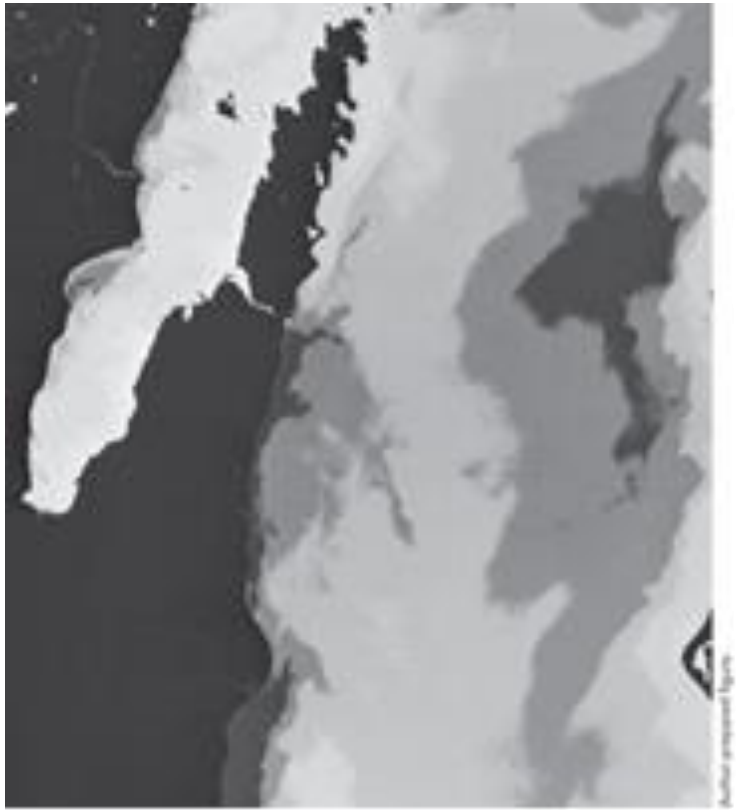


Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

2. **Level slicing:**

   This procedure is used to segment an input image into two image; one for those pixels having values below an analyst-defined gray level & one for those above this gray level value.



Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

3. Contrast stretching:

Image display & recording devices typically operate over a range of 256 gray-level, some could go to up to 2^{13}.

Nevertheless, sensored data in a single image rarely extend over this entire range of values. Hence, the goal of contrast stretching is to expand the narrow range of brightens values typically present in an input image over a wider range of gray levels.

Contrast stretching is applied primarily to improve visual image analyses but the original image should not change.

Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

3. Contrast stretching: *(continue)*

There are at least three types of contrast stretch methods, linear stretch, special leaner stretch, & histogram equalized stretch.

In leaner stretch we usually apply an algorithm similar to the following;

If DN $\leq$ Min => DN' = zero; else,

If DN $\geq$ MAX => DN' = Maximum value in the range; else,

$$DN' = [(DN - MIN)/(MAX - MIN)] * Range$$

Where, DN is the is the input digital value of the original image,

Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

3. Contrast stretching: *(continue)*

DN' is the is the output digital value of the image,

MIN is the maximum value of the input image to be assign a value of zero on the output image,

MAX is the minimum value of the input image to be assign a value of maximum value in the range on the output image,

Range is the maximum value in the display range of value.

Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

3. Contrast stretching: *(continue)*

In special leaner stretch we define the values of MIN & MAX instead of getting them from the image.

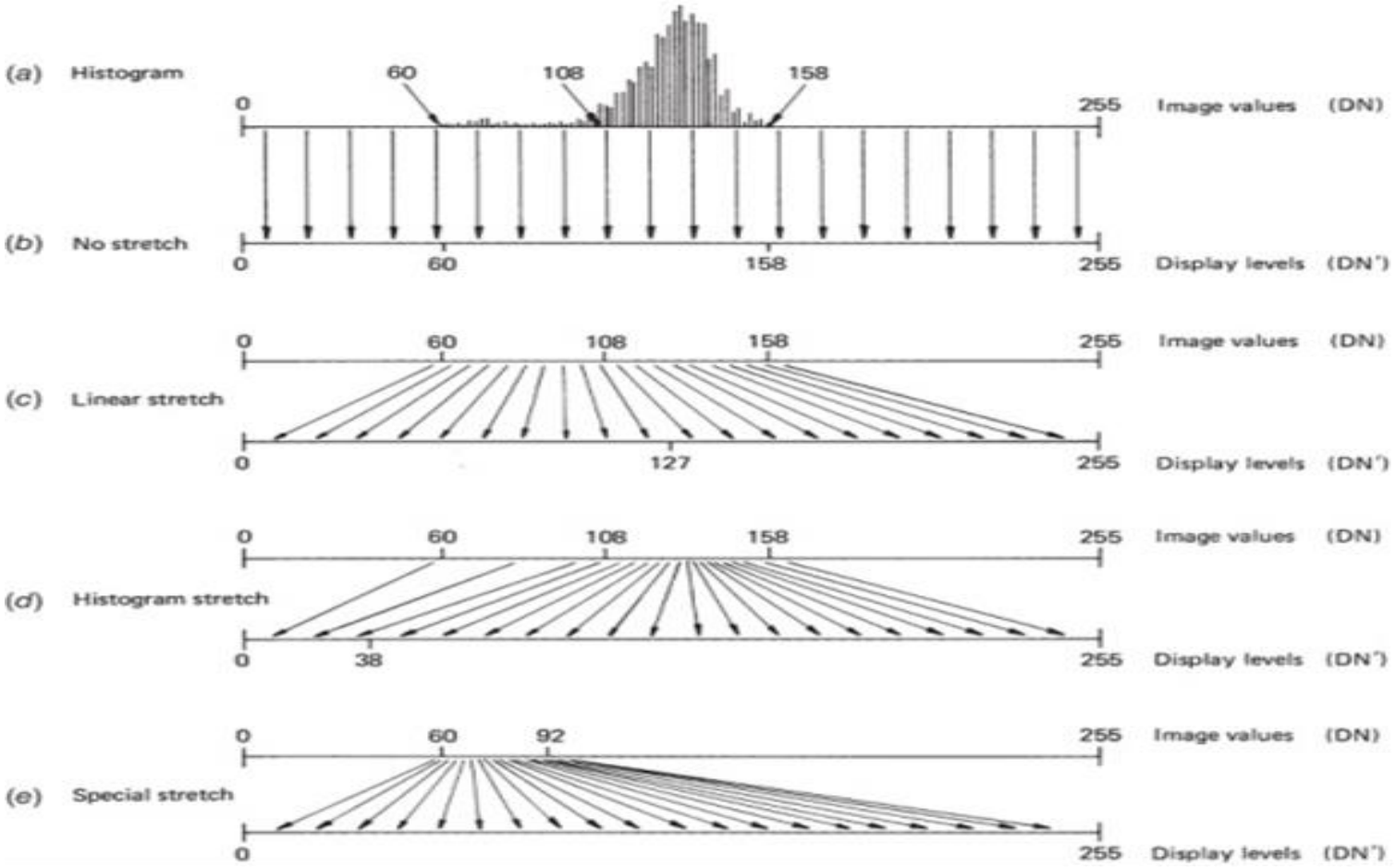
However, to improve on the above stretch method a histogram equalized stretch can be applied.

In this approach, image values are assigned to the display levels on the basis of their frequency of occurrence.

Chapter 4: "Image Enhancement"

Contrast Manipulations: *(continue)*

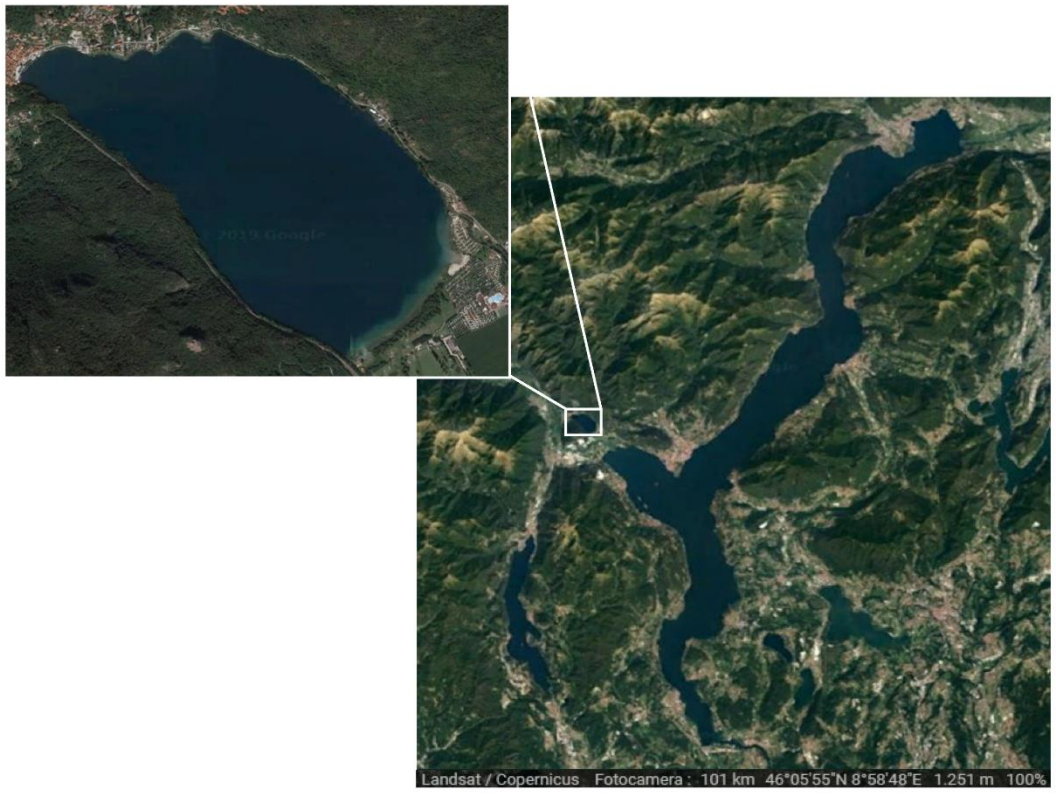
3. Contrast stretching: *(continue)*



Chapter 4: "Image Enhancement"
Part 2 out of 3

Spatial Feature Manipulations:

Of the many possible feature manipulations only five operations will be consider here, namely; image reductions, image magnifications, spatial filtering, edge enhancement, & Fourier analysis.



Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

1. Image reductions, or zoom out:

To reduce a digital image to just $1/m^2$ of the original image data, every m^{th} row & m^{th} column of the imagery are systematically selected & displayed.

2	2	4	4	6				
1	2	4	5	6		2	4	6
1	1	5	6	6		1	5	6
0	1	3	3	4		0	2	4
0	1	2	3	4	(b) Reduced image.			
(a) Original image.								

Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

2. Image magnifications, or zoom in:

To magnify a digital image by a factor of m of the original image data, each pixel in the original image is usually replicated by an m x m block of pixels, all with the same brightness value as the original input pixel.

					2	2	4	4	5	5
	2	4	5		2	2	4	4	5	5
	1	5	6		1	1	5	5	6	6
	1	2	3		1	1	5	5	6	6
	(a) Original image.				1	1	2	2	3	3
					1	1	2	2	3	3
					(b) Magnified image.					

Chapter 4: "Image Enhancement"

***Spatial Feature Manipulations:** (continue)*

3. Spatial filtering:

Spatial filtering emphasize or deemphasize image data of various spatial frequencies.

For example, Low pass filters are designed to emphasize low frequency features, large area changes, & deemphasize high frequency components of the image.

High pass filters will do just the opposite.

Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

3. Spatial filtering: (continue)

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

(a) Kernel

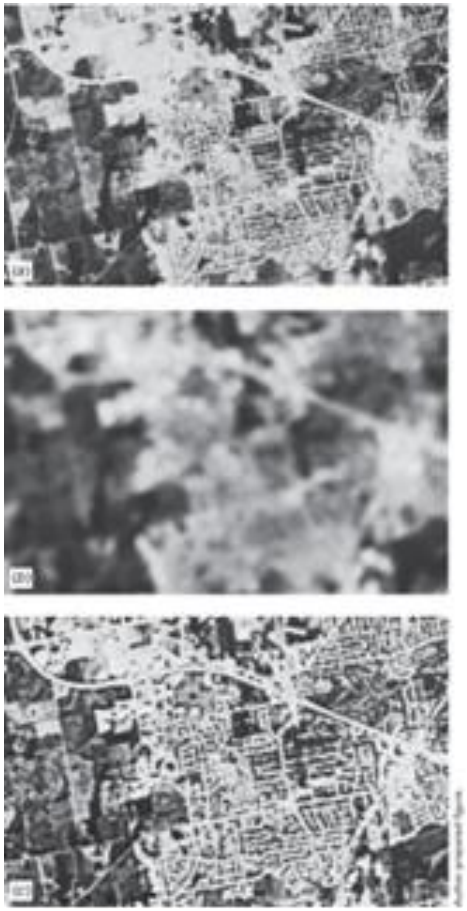
67	67	72
70	68	71
72	71	72

(b) Original image DNs

	70	

(c) Convolved image DN

Convolution: 1/9(67) + 1/9(67) + 1/9(72) + 1/9(70) + 1/9(68) + 1/9(71) + 1/9(72) + 1/9(71) + 1/9(72) = 630/9 = 70



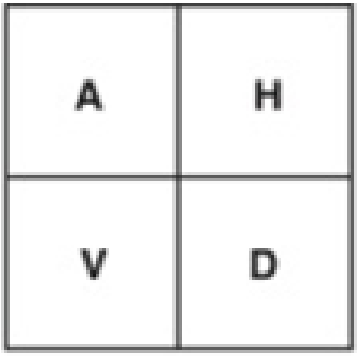
(a) Original image, (b) low pass image, (c) High pass image, Lillesand et al 2015.

Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

4. Edge enhancement:

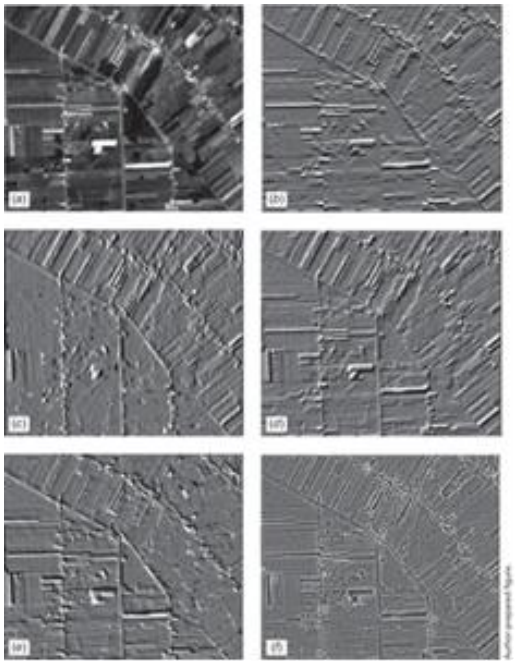
Edge enhancement is applied to images to exaggerate local contrast & to enhance linear features or edges in the image data, see Figures.



Horizontal first difference = $DN_A - DN_H$

Vertical first difference = $DN_A - DN_V$

Diagonal first difference = $DN_A - DN_D$



Samples of different edge images, Lillesand et al 2015.

Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: (continue)

5. Fourier analysis:

Fourier analysis can work as an image enhancement & it also can remove the line stripping effects form a defected image.

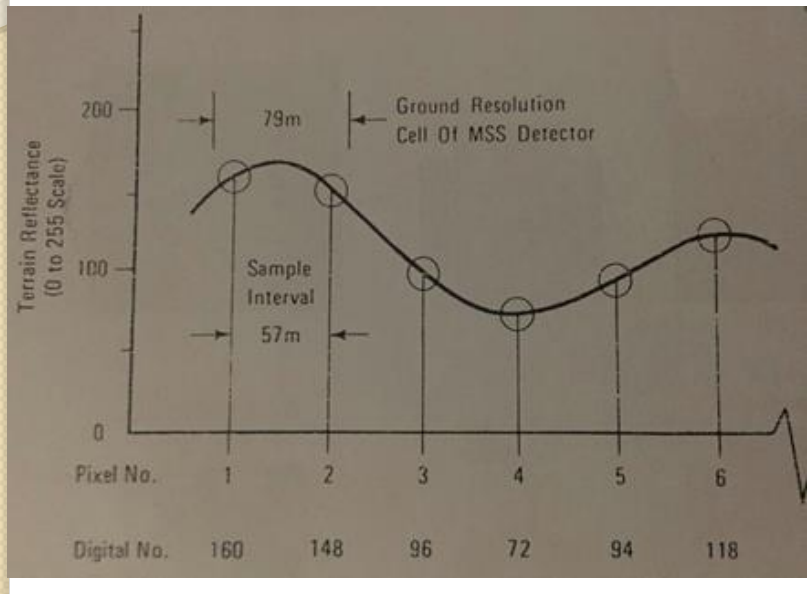
In this approach, an image is separated into various spatial frequency components by a mathematical operation known as the Fourier or Fast Fourier Transformation.

After the image is reassigned in the frequency domain, it is transferred back to the spatial domain.

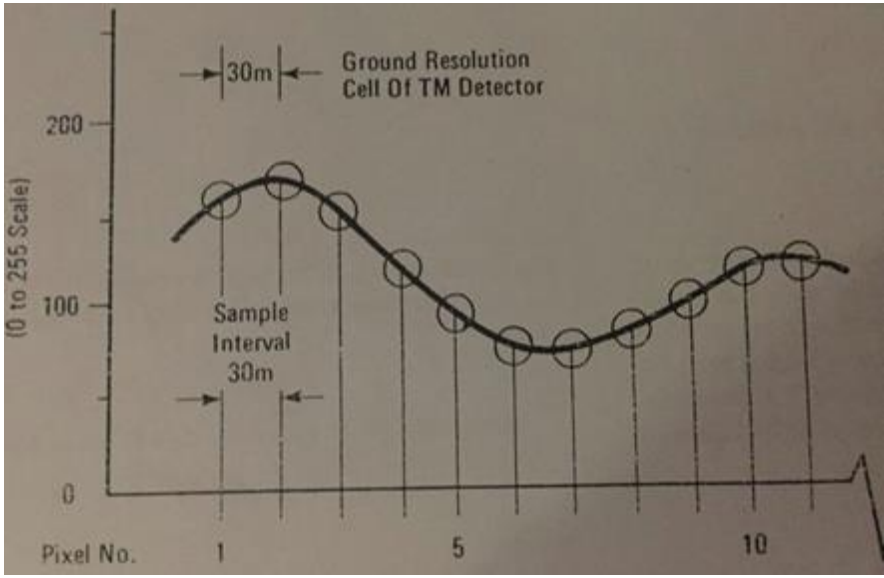
Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

5. Fourier analysis: (continue)



(a) Frequency of values at one line of a ban in MSS image.

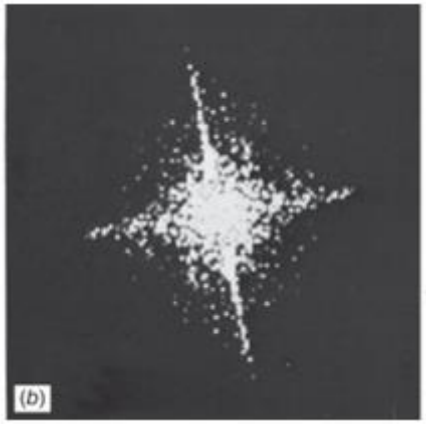


(b) Frequency of values at one line of a ban in TM image.

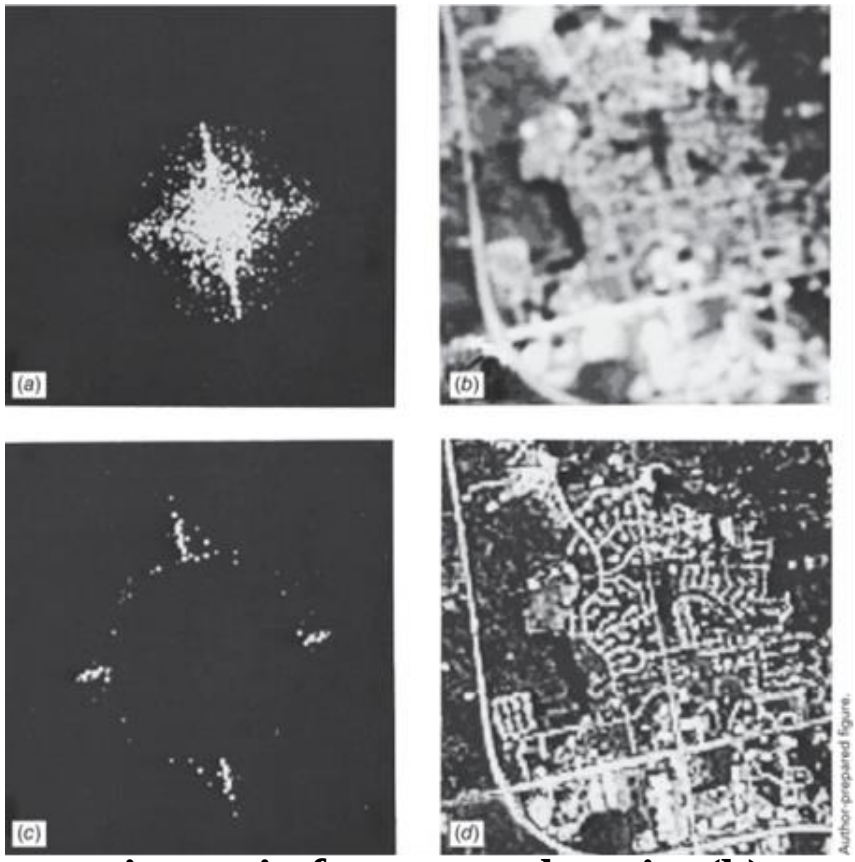
Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

5. Fourier analysis: (continue)



(a) Image in spatial domain, (b) image in frequency domain.



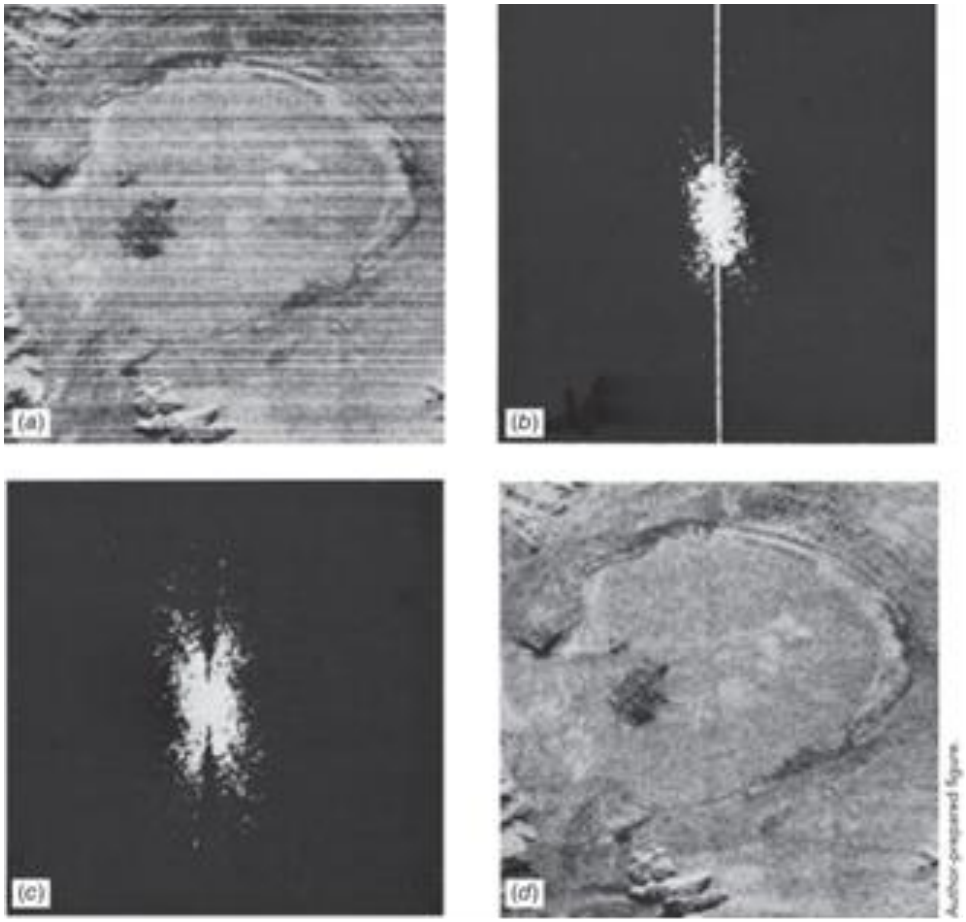
(a) Low pass image in frequency domain, (b) Low pass image in spatial domain, (c) high pass image in frequency domain, (d) high pass image in spatial domain, Lillesand et al 2015.

Chapter 4: "Image Enhancement"

Spatial Feature Manipulations: *(continue)*

5. Fourier analysis: (continue)

(a) Original image with line stripping effects in spatial domain, (b) original image in frequency domain, (c) image in frequency domain after applying a step wedge filter, (d) filtered image after transforming it back to the spatial domain with no line stripping effects, Lillesand et al 2015.



Chapter 4: "Image Enhancement"
Part 3 out of 3

Multi-Image Manipulations:

There are many operations in Multi-image manipulation, but as with the previous two types of image enhancement categories only four of them will be discussed here, namely;

1. Spectral Ratioing,
2. Vegetation Index, VI,
3. Principal Component Analysis, PCA, &
4. Intensity-Hue- Saturation, IHS.

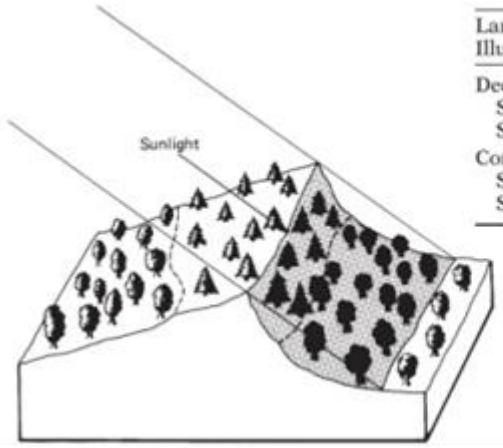
Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

1. Spectral Ratioing:

Ratio images are enhancements resulting from the division of DN values in one spectral band by the corresponding values in another spectral band.

A ration transformation will emphasize in some information & deemphasize on some others.



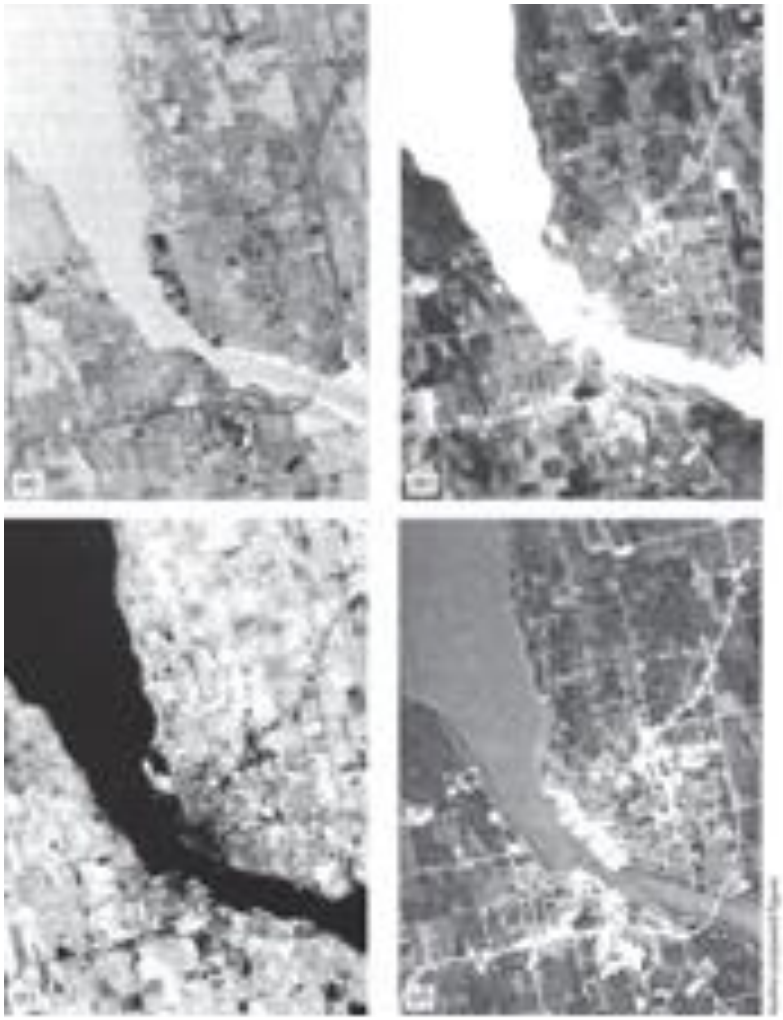
	Digital Number		
Land Cover/ Illumination	Band A	Band B	Ratio (Band A/Band B)
Deciduous			
Sunlit	48	50	0.96
Shadow	18	19	0.95
Coniferous			
Sunlit	31	45	0.69
Shadow	11	16	0.69

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

1. **Spectral Ratioing: (continue)**

Some of the well-known ratio transformations that will be discussed here are the angle ratio transformation & the difference ratio transformation.



Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

1. **Spectral Ratioing: (continue)**

(i) **Angle ratio transformation; the output digital number (DNi') of this ratio can be found by;**

$$DNi' = R \arctan [DNyi / (DNxi + 1)]$$

Where,

R is a constant = 162.3, for 8-bit quantization level,

Arctan is the tangential inverse of the angle in rad, &

Dnxi & DNyi are the digital number values in x & y bands.

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

1. **Spectral Ratioing: (continue)**

(ii) ***difference ratio transformation; the output digital number (DNi') of this ratio, for 8-bit quantization level, can be found by;***

$$DNi' = [1 + (DNyi - DNxi) / (DNyi + DNxi + 1)] * 127$$

Where,

127 is a constant for 8-bit quantization level, &

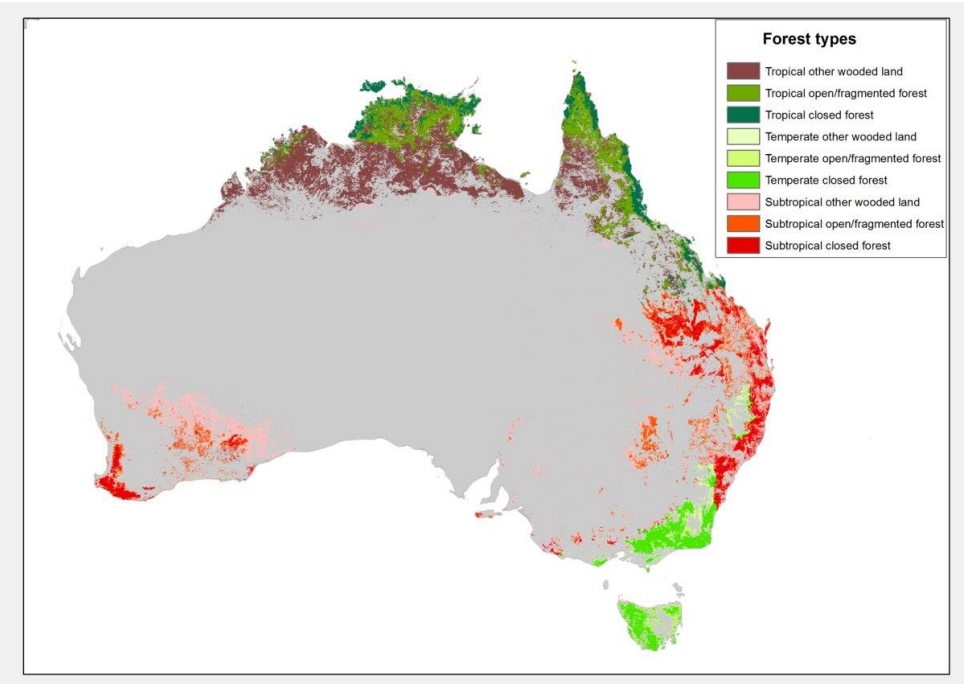
Dnxi & DNyi are the digital number values in x & y bands.

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

2. Vegetation Index, VI:

Vegetation Index, VI is about the collection of accurate, timely information on the world's food crops, through the measurement of vegetative amount & condition based on an analysis of remotely sensed spectral measurements.



Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

2. Vegetation Index, VI: (continue)

The transformed vegetation index (TVI), as an example is given by;

$$TVI = \{[(DN_{N-IR} - DN_{Red}) / (DN_{N-IR} + DN_{Red})] + 0.5\}^{1/2} * 100$$

Where,

DN_{N-IR} **&** DN_{Red} **are the digital number values in the near-IR & red bands.**

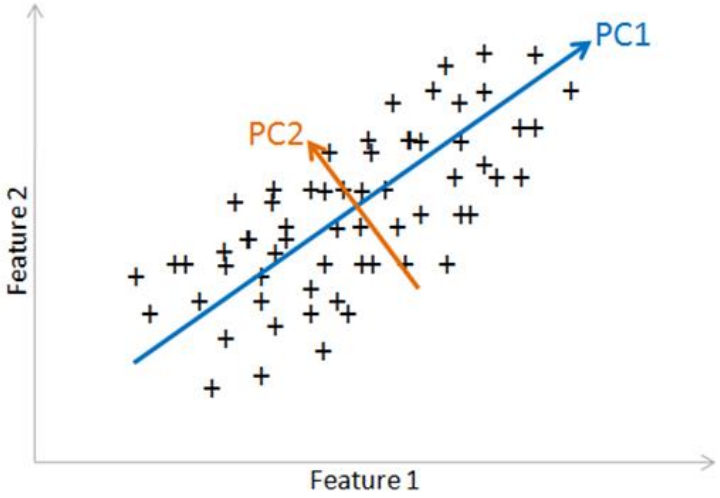
Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

3. Principal Component Analysis, PCA:

In PCA, data are transformed along orthogonal axes that are dependent on the variance within the image.

The first PC is along the axis of the maximum variance. Each succeeding axis is orthogonal to other axes & it has less variance.



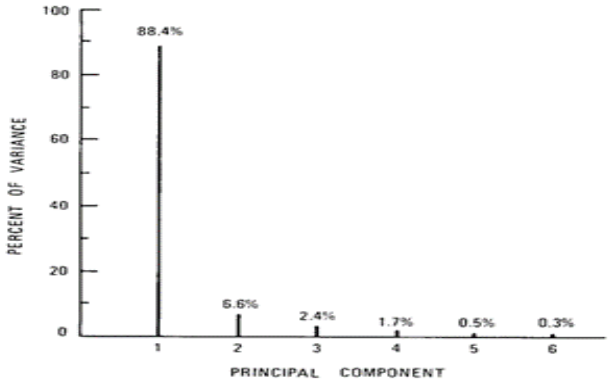


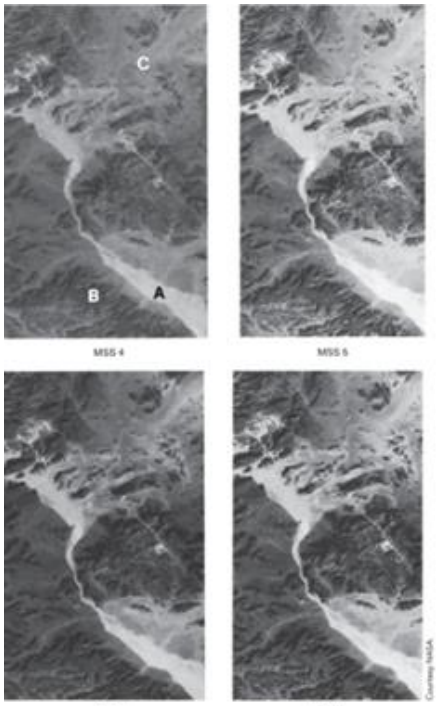
FIGURE 7.25 Percentage of variance represented by the six PC images of the Thermopolis subscene from Landsat TM data.

Chapter 4: "Image Enhancement"

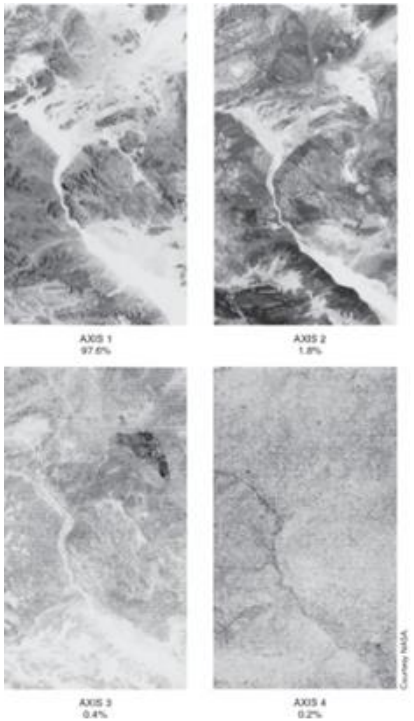
Multi-Image Manipulations: *(continue)*

3. Principal Component Analysis, PCA: (continue)

The purpose of these procedures is to compress all of the information contained in an original-channel data set into fewer than "n" new components.



Original 4-band MSS image, Lillesand et al 2015



4-band PCA image, Lillesand et al 2015

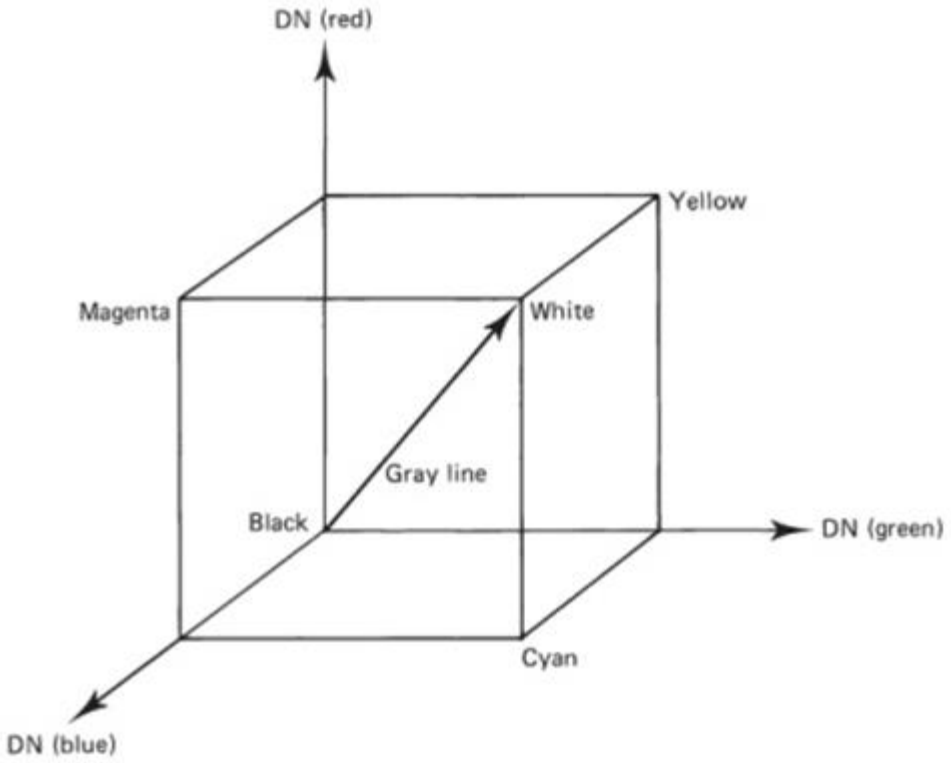
Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS:

The color of any input pixel can be represented by 3-D coordinates in the RGB space system, known as the color cube.

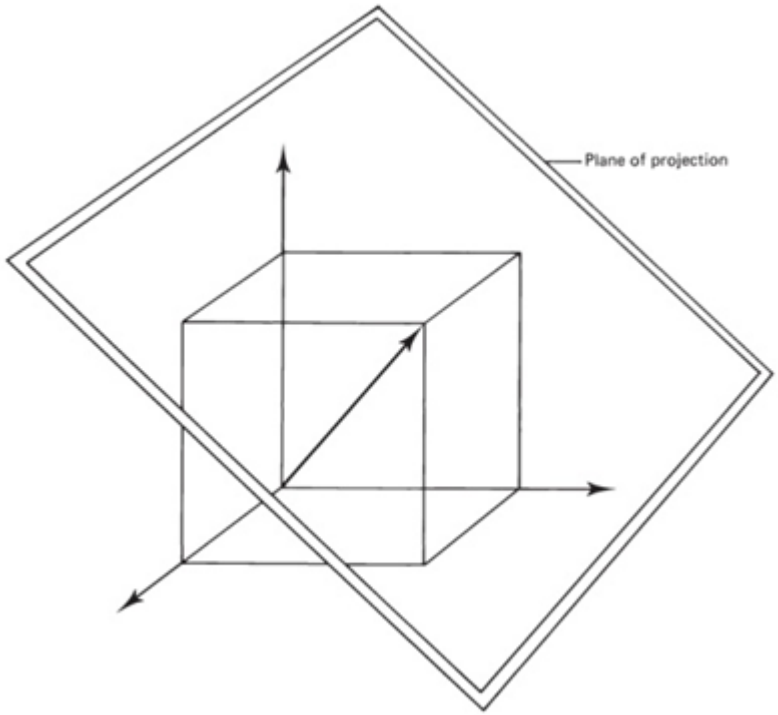
In this cube, each axis represent one primary color, blue, green, & red.

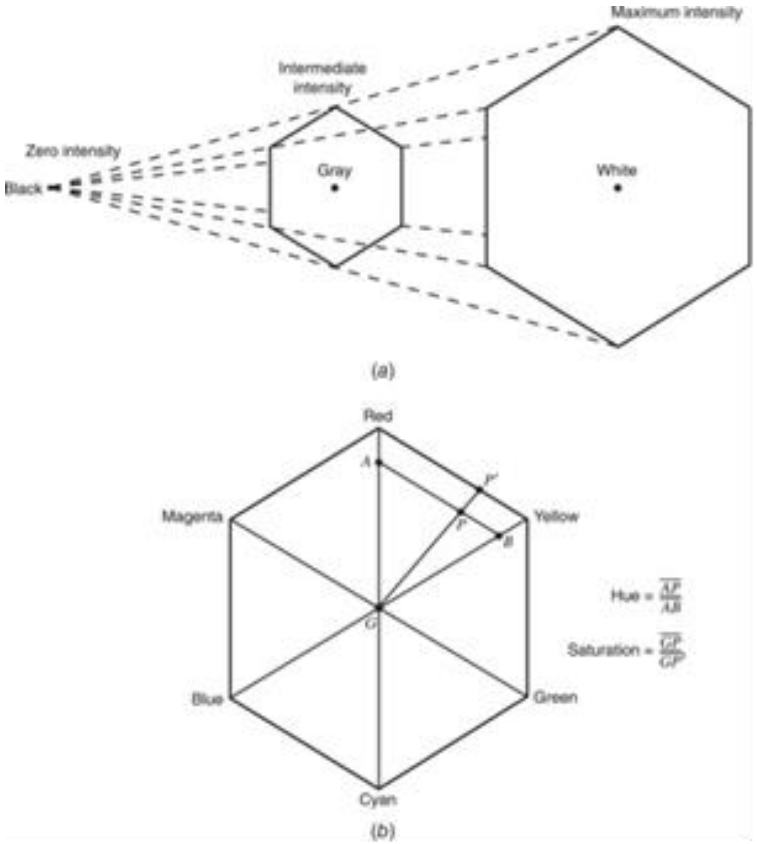


Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS:





A flat surface running perpendicularly to the gray line into the color cube, Lillesand et al 2015.

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS: (continue)

Along each axis, only the values of this color will change, the other two will remain zeroes. The point of the origin, where all three values are equal to zero, is going to be black.

The point where each of the tree values are equal to 255 is going to be white.

The line connecting black & white is the gray line in which every point on this line has equal values of blue, green, & red. This line represent the Intensity of the image where there are no information of the colors of the image.

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS: (continue)

Intensity-hue-saturation, HIS, color image representation system can be defined as a set of cylindrical coordinates in which the height, angle, & radios represents intensity, hue, & saturation, respectively.

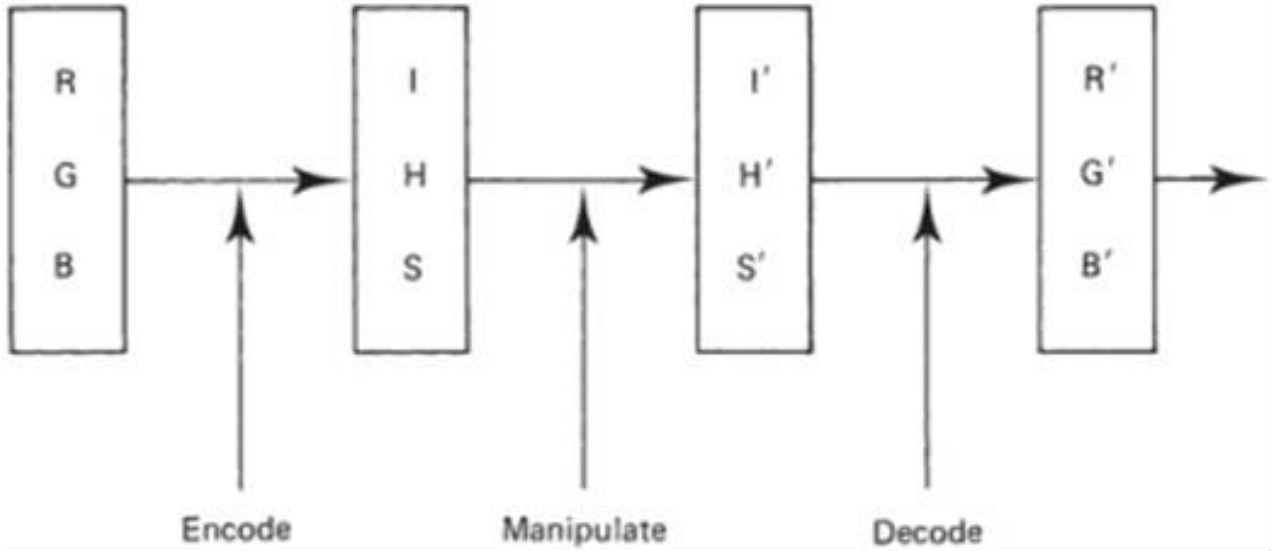
Thus for any particular color: intensity represents the overall brightness irrespective of color, hue represents the specific mixture of wavelengths that define the color, & saturation represents the boldness of the color.

Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS: (continue)

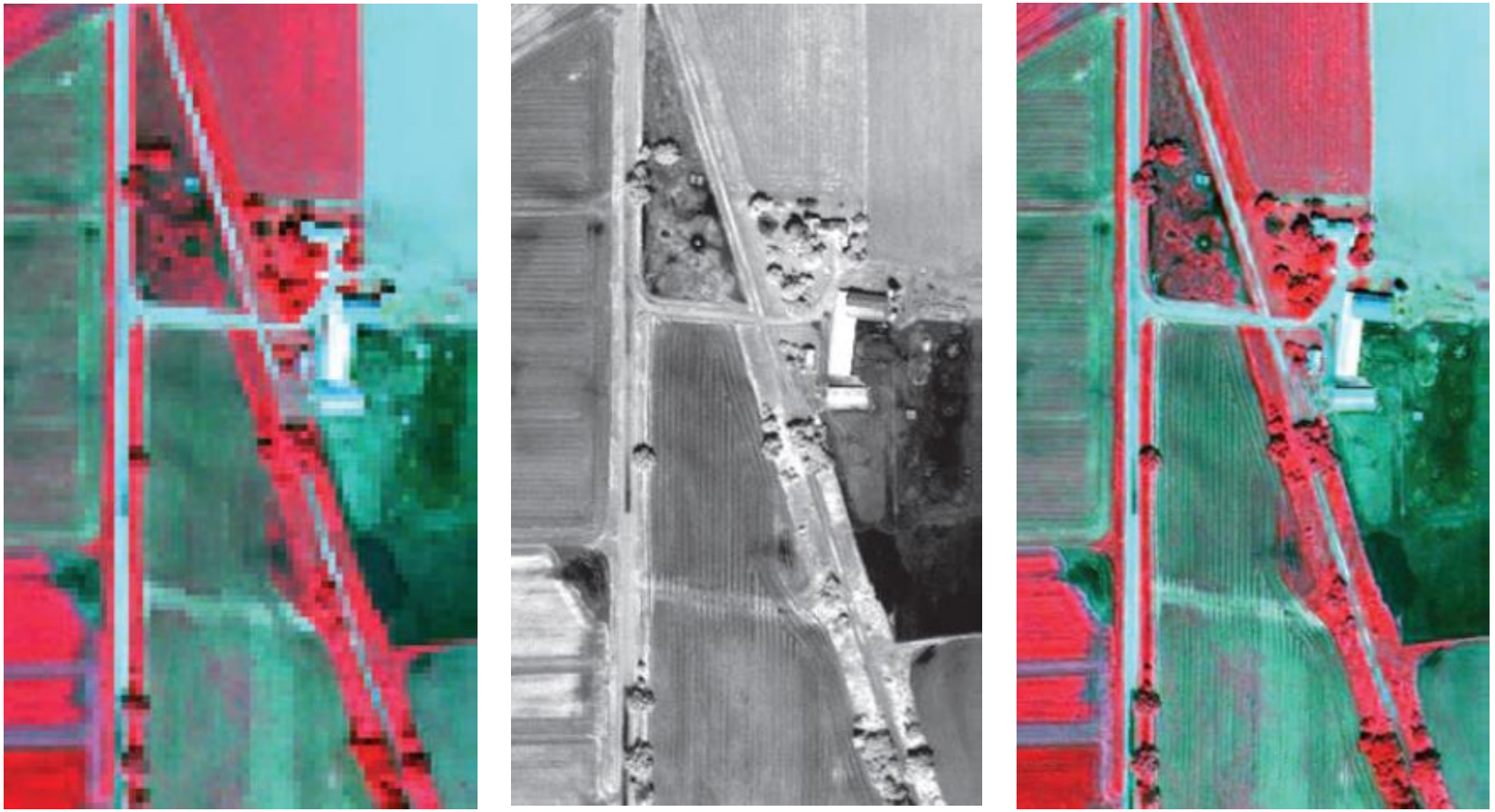
Transforming RGB components into IHS components before processing may provide more control over color enhancement.



Chapter 4: "Image Enhancement"

Multi-Image Manipulations: *(continue)*

4. Intensity-Hue- Saturation, IHS: (continue)



Left 4m color image, center 1m panchromatic image, & right pan-sharpened image.