Lecture 7
Image Processing

2017

Ref: Lecture Notes from Dr. Honda, AIT Thailand

Filtering (Digital)

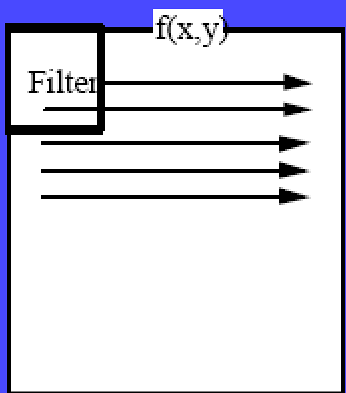
- Feature Extraction
- Noise Suppression or Speckle Reduction
- Image Enhancement

Speckle reduction filtering consists of moving a small window of a few pixels in dimension (e.g. 3x3 or 5x5) over each pixel in the image, applying a mathematical calculation using the pixel values under that window (e.g. calculating the average), and replacing the central pixel with the new value.

The window is moved along in both the row and column dimensions one pixel at a time, until the entire image has been covered. By calculating the average of a small window around each pixel, a smoothing effect is achieved and the visual appearance of the speckle is reduced. (Ref. Fundamental of RS by CCRS)

PSF = Point Spread Function

Spatial Filter Operation



PSF(x,y)
(FILTER)

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

f(x,y) j

i

5	6	7	8	9
11	10	20	30	9
31	50	60	70	9
40	30	20	10	9
58	95	105	106	98

10x1/9+20x1/9+30x1/9
+50x1/9+60x1/9+70x1/9
+30x1/9+20x1/9+10x1/9
= 33

g(i,j) = 33

$$g(i,\ j) = \sum_{m=i-W/2}^{i+W/2} \sum_{n=j-W/2}^{j+W/2} f(m,n)\, PSF(i-m,\ j-n)$$

- Smoothening can be done be selecting median instead of mean. Median has advantage that it will result in value present in the data.

Various Filters

Smoothing

1/9 ×

1	1	1
1	1	1
1	1	1

Laplacian

-1	-1	-1
-1	1	-1
-1	-1	-1

Sharpening

1/9 ×

1	-8	1
-8	37	-8
1	-8	1

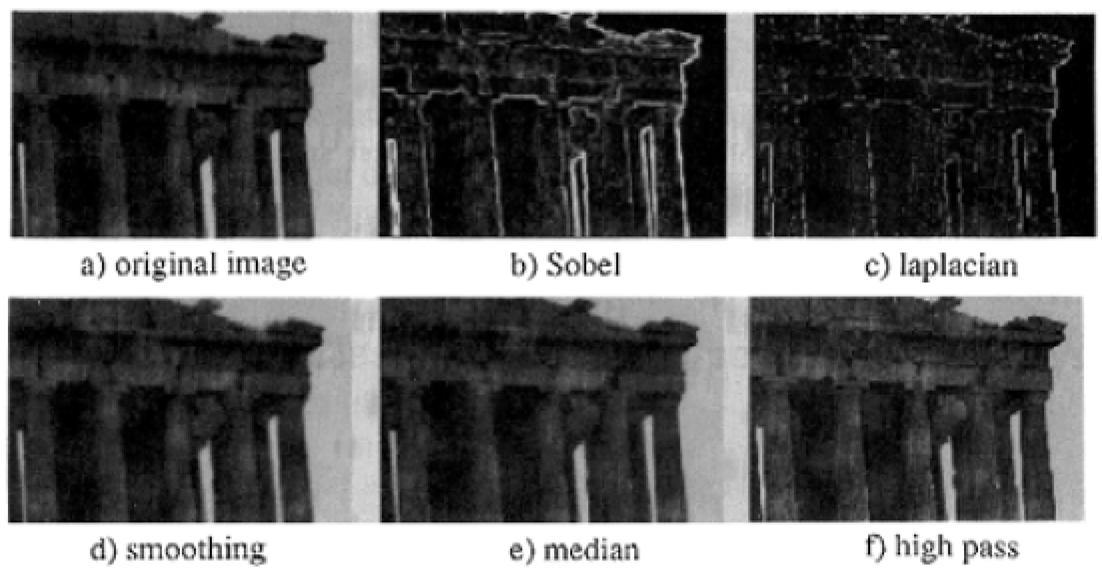


Figure 10.9.2 Image enhancement with use of 3x3 operators

Types of Filters

- Smoothing (for noise removal)
  - Mean
  - Median

$$\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}$$

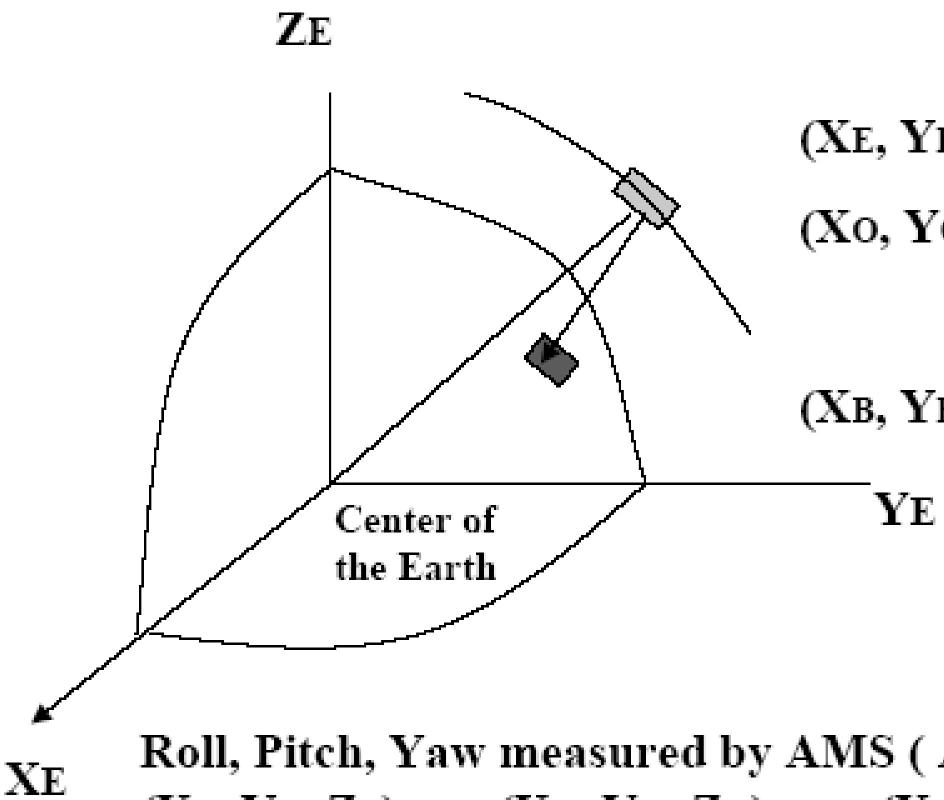
- Sharpening (for contrast enhancement)

$$\begin{bmatrix} -1/9 & -1/9 & -1/9 \\ -1/9 & 8/9 & -1/9 \\ -1/9 & -1/9 & -1/9 \end{bmatrix}$$

- Directional (for edge detection)
- Laplacian (for edge detection)

http://northstar-www.dartmouth.edu/doc/idl/html_6.2/Filtering_an_Imagehvr.html#wp1027824

Coordinate System



(X_E, Y_E, Z_E): Earth based Coordinate

(X_O, Y_O, Z_O): Satellite Orbit Coordinate along the orbit

(X_B, Y_B, Z_B): Satellite Based Coordinate rotate satellite orbit coordinate with Roll, Pitch and Yaw

Roll, Pitch, Yaw measured by AMS (Attitude Measurement Subsystem)
(X_E, Y_E, Z_E) <-> (X_O, Y_O, Z_O) < -> (X_B, Y_B, Z_B)
(X_E, Y_E, Z_E) of target-> Longitude, Latitude -> Map Projection such as UTM

Map Projection

- A **map projection** is used to project the rotated ellipse representing the earth's shape, to a two-dimensional plane. However there will be some distortions because the curved surface of the earth cannot be projected precisely on to a plane.
- There are three major map projection techniques; perspective projection, conical projection and cylindrical projection, which are used in remote sensing. There are described as follows.
- a. Perspective projection
- b. Conical projection
- c. Cylindrical projection

- UTM is a type of **Gauss-Kruger projection**, with the meridian tangent to the cylinder. The UTM has an origin point at every six degrees of longitude with a scale factor of 0.9996 at the origin and 1.0000 at a distance of 90 kilometers from the central meridian.

Perspective Projection

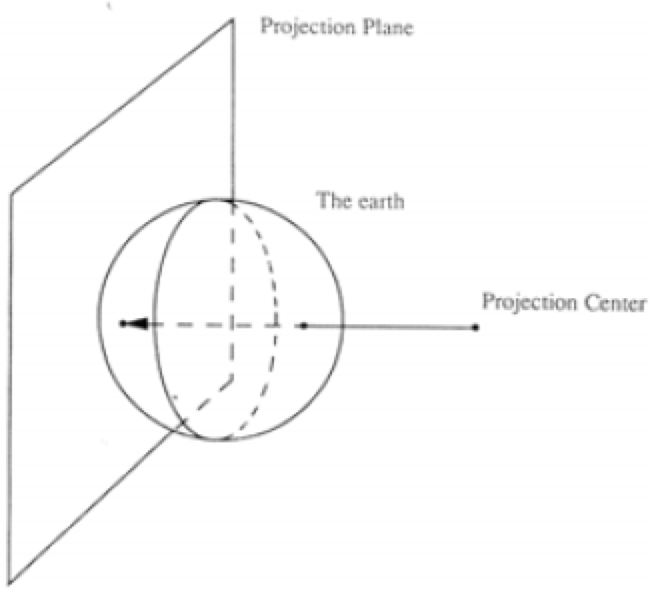


Figure 9.8.1 Perspective projection

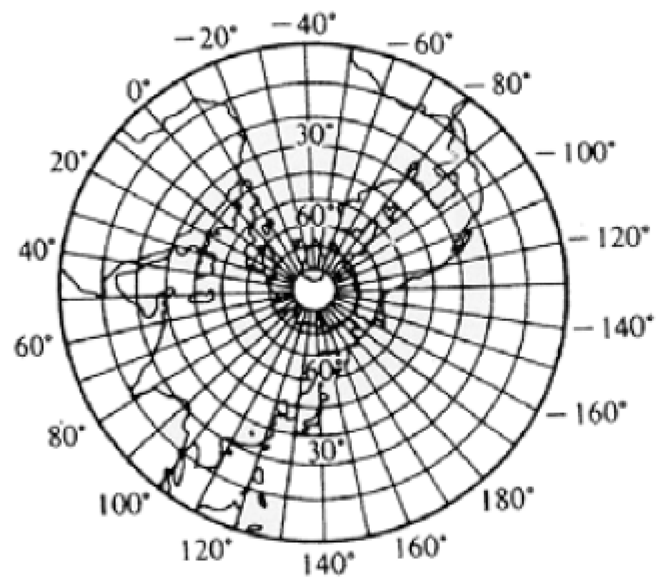


Figure 9.8.2 Polar stereo projection

Gauss-Kruger Projection

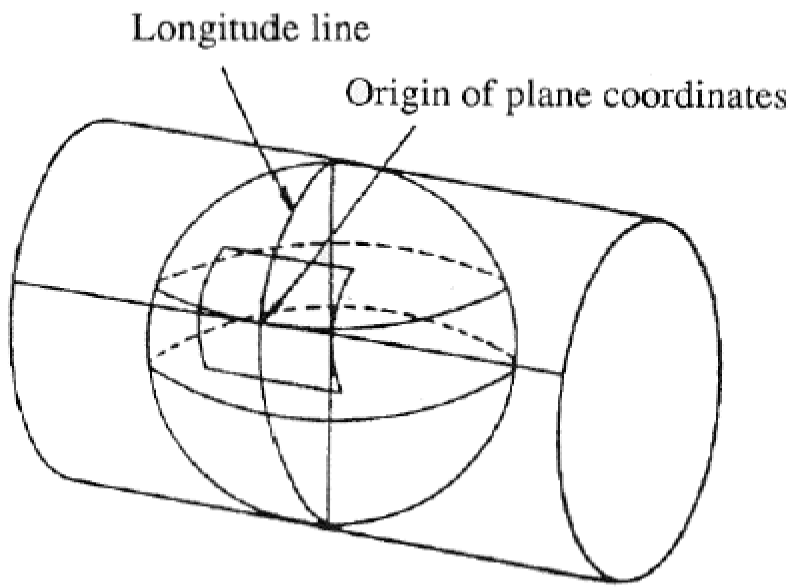
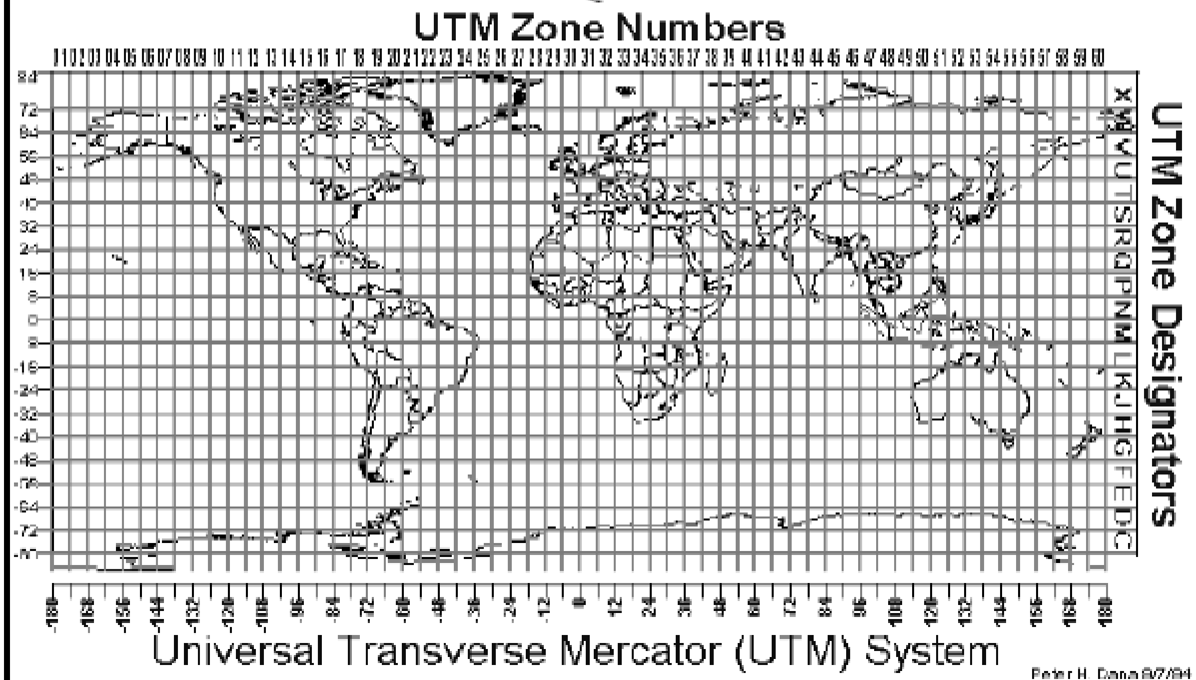
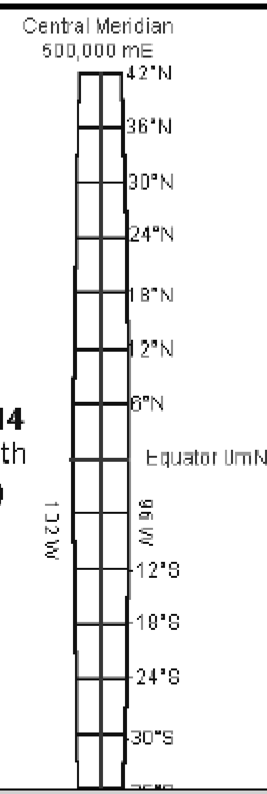


Figure 9.8.4 Gauss-Krueger projection

UTM



UTM Zone 14
(from 42°South to 42°North)



UTM: Universal Transverse Mercator

Project every 6 degree of longitutde to one flat plane from –80 to +80 deg latitude

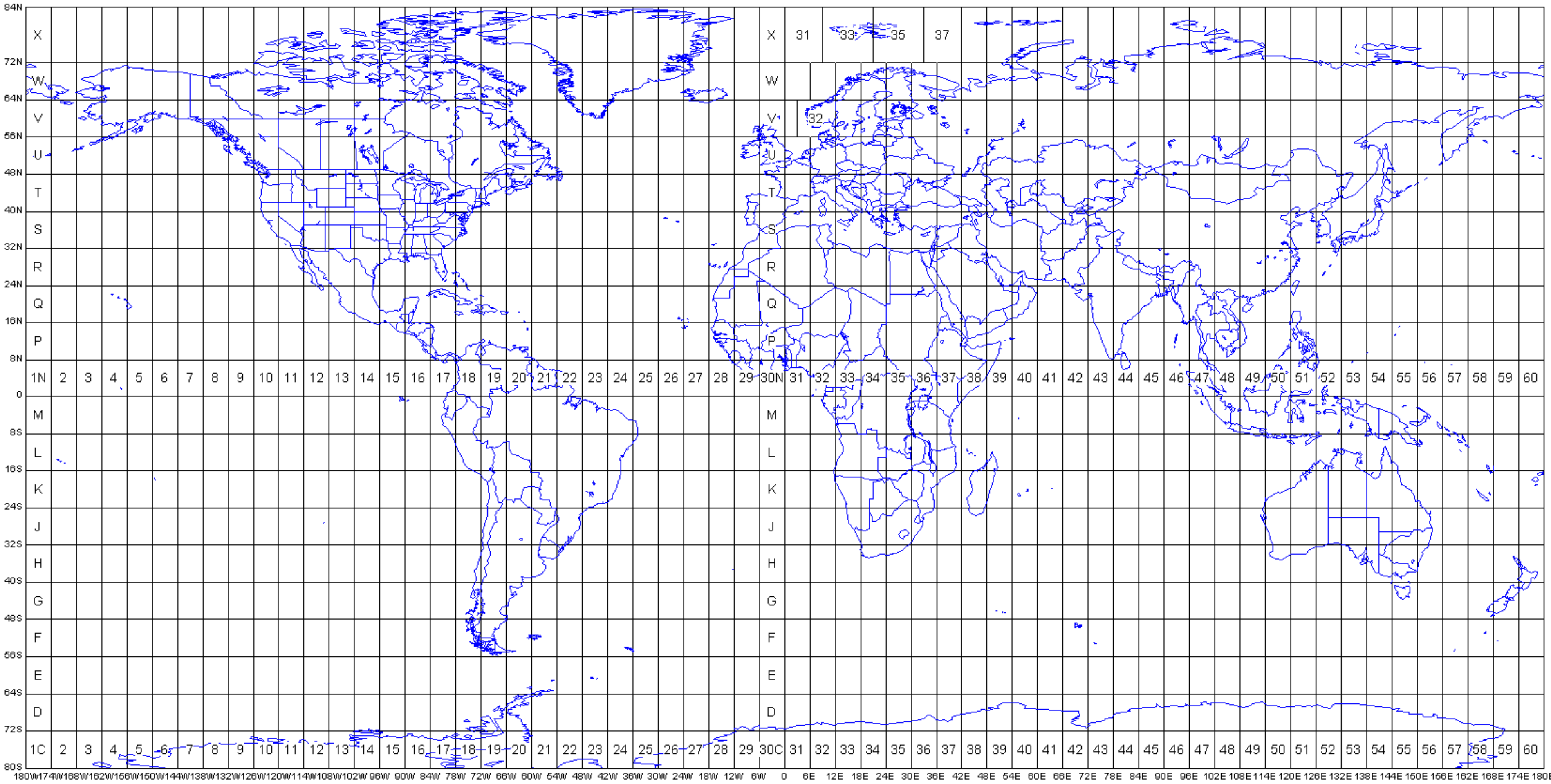
Easting: measured from the center, but to ensure all coordinate be positivie,
500km is added.

Northing: For north hemisphere, measure from equator,
for south hemisphere, 10,000km is added

Thailand: Zone 47 Pakistan, 41, 42 and 43

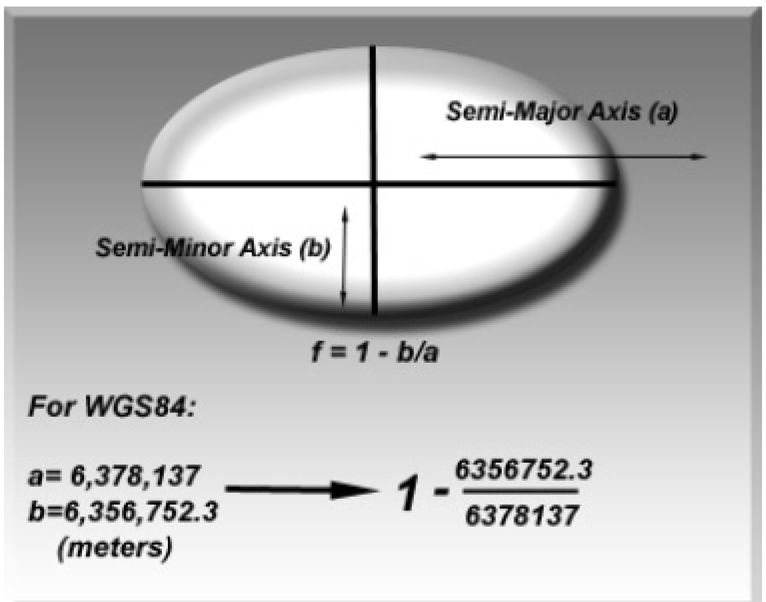
- UTM is a type of **Gauss-Kruger projection**, with the meridian tangent to the cylinder. The UTM has an origin point at every six degrees of longitude with a scale factor of 0.9996 at the origin and 1.0000 at a distance of 90 kilometers from the central meridian.

UTM zones



Ref: http://www.dmap.co.uk/utmworld.htm

Ellipsoid



Many Ellipsoid

- **GRS80**
- **WGS84**
- **Everest 19XX**
- CLARKE 1866

Many country started to use GRS80, which is based on satellite observation WGS84 and GRS80 is nearly same. (several 10cm and meter difference)

ITRF adopt GRS80
ITRF(International Terrestrial Reference Frames) which is 3 axis coordinate system (X,Y,Z), and the origin is the center of the gravity of the earth.

Datum

- Datum is a set of parameter, which defines the size and the position of the earth.
- Thus if Datum is different, geo-locations changes.
- There are many datum even though they use same ellipsoid to have best applicability to the region in terms of accuracy, implementation.
- Many countries started to implement IRTF Datum.
- When you locate a position on your map, the datum of the position information and the datum used in the map must be same.
- Usually RS image is being projected to UTM using WGS84 (with WGS84 ellipsoid) datum. However you can select IRTF - GRS80 as well for Landsat
- GPS: Default: WGS84 for usual GPS, ITRF for high-precision GPS. You must check the datum used in your map, and adjust GPS receiver to use the same datum.

ITRF= International Terrestrial Reference Framework

Geometric Correction

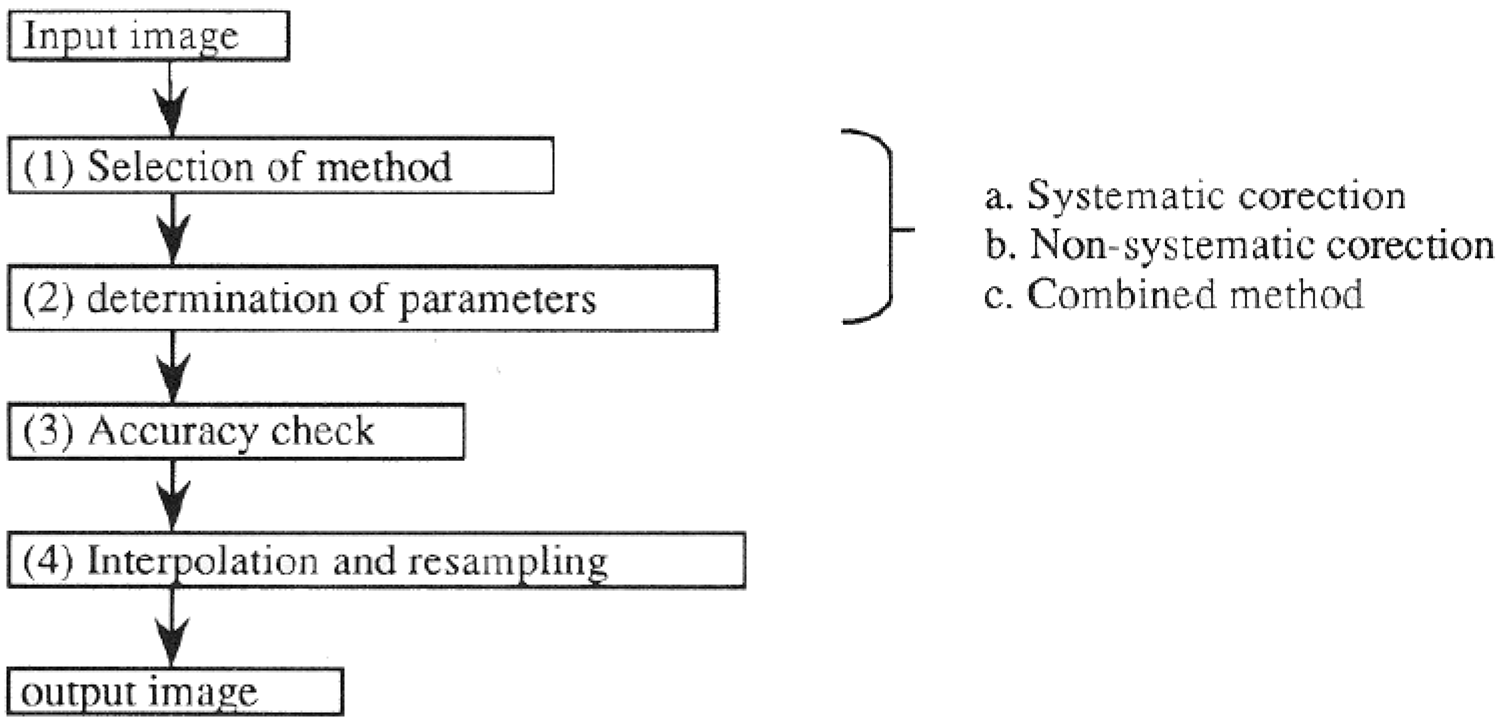


Figure 9.4.1 The flow of geometric correction

Steps of Usual Non-systemaic Geometric Correction

Locate the image exactly on a map coordinate, by re-projecting the image, so that location of each pixel can be identified correctly.

1. Make a list of Image Coordinate and their position using GCP.
2. GCP (Ground Control Point) is taken from such as intersection, corner of reclamations, capes, small islands, river joint point and etc.
3. GCP should be able to be identified both in image and map (or GPS)
4. If Map is not available, GPS is used to obtain coordinates.
5. Select an appropriate transformation equation (usually affine is OK)
6. Re-project the image into the map coordinate
7. usually Cubic Convolution is used as Re-sampling method.

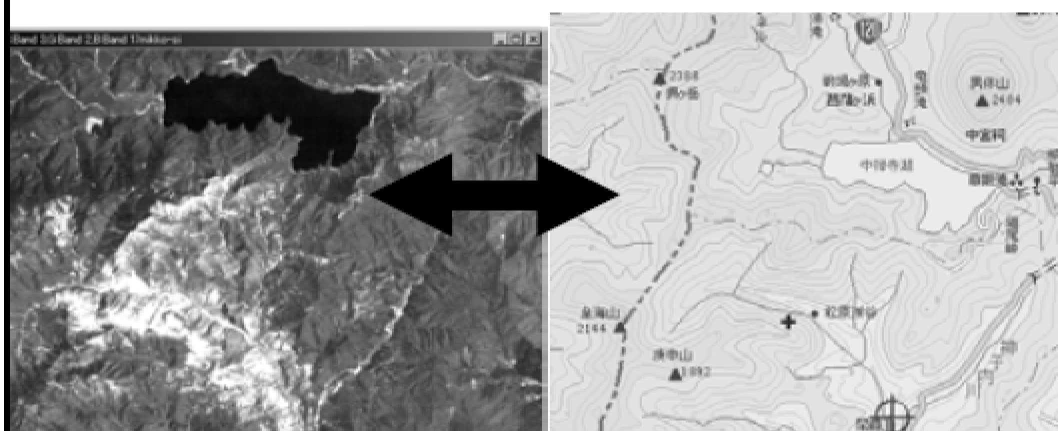


Image Coodinate		Map Coordinate	
Colume	Line	Easting	Northing
390	400	524,445	1,234,456
700	420	525,445	1,234,256
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...

Following types of points are often chosen for GCP

boundaries of land and water, e.g.
corner of reclamations, dams, breakwaters,
corner of harbors,
capes, lighthouses, small islands,
factories, buildings, runways of airport,
center of small poonds,
river joint point, road cross point

Transform formulas I

(x,y) map coordinate system
(u,v) image coordinate system
These 3 transform formulas are often used.
Transform direction is map to image.

Affine transformation

scale, rotate, shift, skew, linear

$$u = a\,x + b\,y + c$$
$$v = d\,x + e\,y + f$$

Pseude affine transformation

$$u = a_1\,x\,y + a_2\,x + a_3\,y + a_4$$
$$v = b_1\,x\,y + b_2\,x + b_3\,y + b_4$$

Polynominals
(n : max 3)

$$u = \sum_{i=1}^{n} \sum_{j=1}^{n} a_{i\,j} x^{i-1}\, y^{j-1}$$
$$v = \sum_{i=1}^{n} \sum_{j=1}^{n} b_{i\,j} x^{i-1}\, y^{j-1}$$

Transform formulas II

Table 9.5.1 Transform formulas

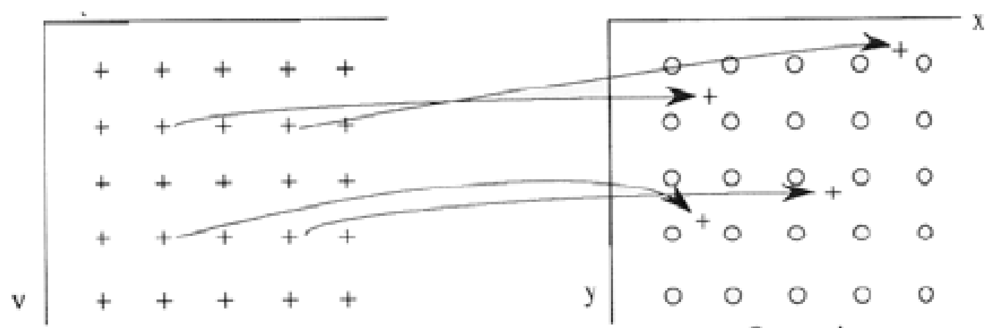
(x, y) : map coordinate system
(u, v) : image coordinate system

Name	Transform formula	Number of unknown parameters
1) Helmert Transform (scale, shift and rotation)	$x = au + bv + c$ $y = -bu + av + d$	4
2) Affine Transform	$x = au + bv + c$ $y = du + ev + f$	6
3) Pseudo Affine	$x = a_1uv + a_2u + a_3v + a_4$ $y = a_5uv + a_6u + a_7v + a_8$	8
4) Projection Transform	$x = \frac{a_1u + a_2v + a_3}{a_7u + a_8 + 1}$ $y = \frac{a_4u + a_5v + a_6}{a_7u + a_8 + 1}$	8
5) Second-order Conformal	$x = a_1u + a_2v + a_3(u^2-v^2) + 2a_4uv + a_5$ $y = -a_2u + a_1v + 2a_3uv - a_4(u^2-v^2) + a_6$	6
6) Polynomials	$x = \Sigma\Sigma a_{ij}\, u^{i-1}\, v^{j-1}$ $y = \Sigma\Sigma b_{ij}\, u^{i-1}\, v^{j-1}$	———

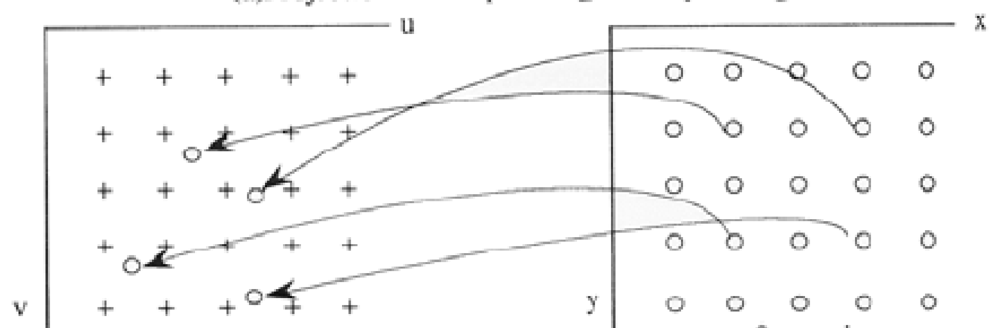
Resampling & Interpolation

- Projection from output image to input image.
  - If output->input, some pixel will not have data
- However, the projected coordinate is not exactly on the grid of a pixel. -> Interpolation from single or several pixels around the projected coordinate.

Resampling



(a)Projection from input image to output image



(b)Projection from output image to input image

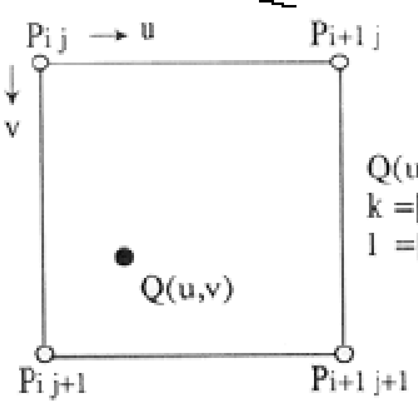
Figure 9.7.1 Resampling Method

Interpolation

- (1) **Nearest neighbor (NN)**
  The nearest point will be sampled. The geometric error will be a half pixel at maximum. It has the advantage of being easy and fast. The data value will not change.

- (2) **Bi-linear (BL)**
  The bi-linear function is applied to the surrounding four points. The spectral data will be smoothed after the interpolation.

- (3) **Cubic convolution (CC)**
  The spectral data will be interpolated by a cubic function using the surrounding sixteen points.The cubic convolution results in sharpening as well as smoothing, though the computation takes a longer time when compared with the other methods.

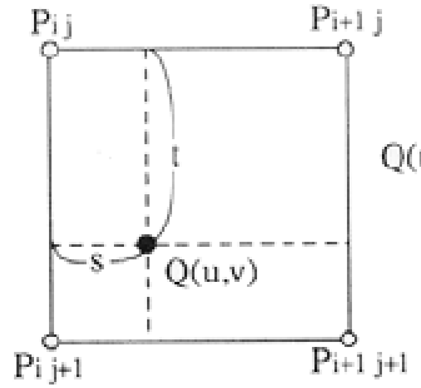


$Q(u,v) = P_{kl}$

$k = [u+0.5]$

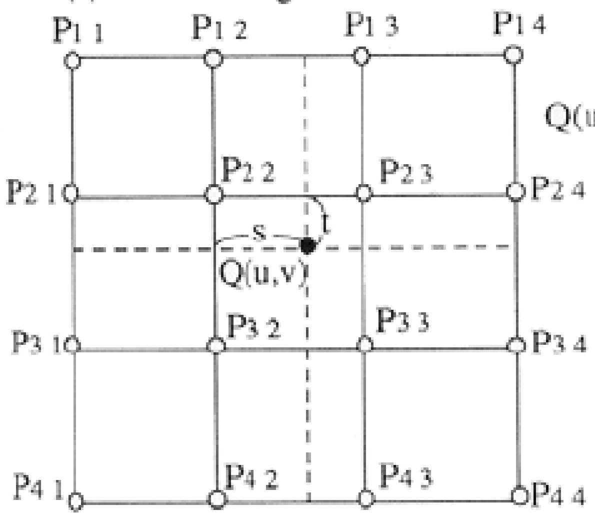
$l = [v+0.5]$

(a) Nearest neighbor



$$Q(u,v) = (1-s)(1-t)P_{ij} - (1-s)t\,P_{i\,j+1} + s(1-t)\,P_{i+1\,j} + s\,t\,P_{i+1\,j+1}$$

(b) Bi -linear



$$Q(u,v) = [f(1+t)\ f(t)\ f(1-t)\ f(2-t)] \begin{bmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \\ P_{41} & P_{42} & P_{43} & P_{44} \end{bmatrix} \begin{bmatrix} f(1+s) \\ f(s) \\ f(1-s) \\ f(2-s) \end{bmatrix}$$

Let

$$f(x) = \sin(\pi x)/(\pi x) \fallingdotseq \begin{cases} 1 - 2|x|^2 + |x|^3 & (0 \leqq |x| < 1) \\ 4 - 8|x| + 5|x|^2 - |x|^3 & (1 \leqq |x| < 2) \\ 0 & (2 \leqq |x|) \end{cases}$$

then

$f(1+y) = -y(1-y)^2$ $\quad f(y) = (1-y) + y(1-y)^2$

$f(1-y) = y + y^2(1-y)$ $\quad f(2-y) = -y^2(1-y)$

(c)Curbic convolution

$Q(u,v)$: A point to be interpolated

P_{ij} : Input image data

[ ] : Gaussian symbol to make integer

$s = u-[u]$, $t = v - [v]$

Figure 9.7.2 Interpolation Method