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Image Map Extraction from Precision Processed Landsat Multispectral Scanner(MSS) and Thematic Mapper(TM) Images *

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Abstract

A unique approach to access Landsat satellite imagery has been implemented on IBM PC microcomputer in order to generate image maps to be used as a substitute and/or supplement for a conventional topographic map. This method enables user to automatically:

- extract a nominal image map,
- geoencode or calibrate as an image map, and
- create a multitemporal image file

using CCTs containing precision processed Landsat MSS and TM images.

These map extraction process includes:

- location of map area in the selected CCT,
- conversion of map coordinates to image coordinates,
- extraction of map area, and
- rotation of image to the true North/South and East/West direction.

1. Introduction

The topographic and related maps are indispensable tools for natural resource managers in their resource management activities. They examine these maps to determine land use, topographic features, transportation networks, hydrologic and geomorphological features, and related land cover information before they go out to field. They also use these maps in field survey work for activities such as locating and recording points of data collection, locating objects on the ground,

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drawing field and other feature boundaries, etc.(Soil Conservation Society of America, 1982). The 1/25,000 and 1/50,000 series topo maps covering entire Republic of Korea are available from National Geographic Institute.

These maps supply useful information on current land use by using color symbolism to depict natural and man made features. However, many of these maps are 5 to 10 years old and thus the changes in land use have not been totally updated. It is not reasonable to expect that such detailed maps(1/25,000) in such large numbers(~830)could be reprinted every 2 or 3 years to keep abreast of evolving land use patterns. Thus, it is important to supplement the more static data contained in these topo maps with more dynamic information extracted from satellite imagery in the form of image maps of the same scale. A unique approach to access Landsat CCTs on the micro-computer was developed to generate image maps and this paper describes its process.

2. Location of Map Area

The first step in the image map extraction process is to determine the location of the desired topo map within the available satellite images. The user or operator selects the desired topo map by name from the map index and the software searches the Map Name Georeference(MNG) files and returns the latitude and longitude of the lower right corner of selected map (Figure 1). The MNG files currently contain the locations of the more than 800 topo maps covering the entire Republic of Korea.

USER'S MAP OF INTEREST

THE MAP WHICH CONTAINS THE POINT IS

INDEX NUMBER : NJ52-14-01
PROVINCE NAME :
COUNTRY NAME :
MAP NAME : CHUNGJU

LOWER RIGHT CORNER = N 36 45 0 / E 128 0 0
UPPER LEFT CORNER = N 37 0 0 / E 127 45 0

Fig. 1. Screen dump of a search for a 1/25,000 map area based on a user specified map name.

There is another option available in the software that allows the user to extract an unknown topo map by entering the latitude and longitude of a single ground point. This software searches through the MNG files, locates the map which contains the specified point within its boundary, and returns the latitude and longitude of the lower-right corner of the map. A third option allows the user to enter the latitude and longitude position of a ground point and specify that he wishes to extract a topo map equivalent map area of an image centered on that point.

3. Identification of Landsat CCT

The four map corners computed from the single corner retrieved from the Map Name Georeference(MNG) file are next used to identify all the available Landsat coverage of the selected map. The software searches the disk files containing Landsat Tape Holding(LTH) files which contains the Landsat tape holdings of all the clearinghouse's members. There are currently about 200 images and 4 members in the clearing house. The names of the four members are Korea Advanced Institute of Science and Technology (KAIST), Korea Institute of Construction Technology (KICT), Korea Institute of Energy and Resources(KIER), and Korea Ocean Research and Development Institute(KORDI). The purpose of this Landsat tape clearinghouse is to exchange information on who holds what Landsat CCTs to serve as a basis for the exchange or purchase of the Landsat tapes from their holders.

The software searches LTH file and compares the desired map corners with each Landsat scene's geographic corners. The resulting list of all available Landsat scenes with full or partial coverage of the map area is then displayed on the terminal(Figure 2). The user examines the partial or full coverage lists, chooses a type and date of a Landsat CCT from the list which best fits his analysis objectives.

K: KAIST O: KORDI E: KIER

FULL COVERAGE OF CHUNGJU IMAGE-MAP							
PATH	ROW	DATE	ID NUMBER	CLOUD(%)	TYPE	OWNER	TAPE-ID
124	34	72/12/5	8113501400500	20	M-1	K 0	CCT004

PARTIAL COVERAGE OF CHUNGJU IMAGE-MAP							
PATH	ROW	DATE	ID NUMBER	CLOUD(%)	TYPE	OWNER	TAPE-ID
124	34	81/12/3	8J22507012510	0	M-2	E	
116	35	83/5/17	E4030501410-0	0	T-4	O	
116	35	83/10/24	E4046501405-0	10	T-4	O	
115	35	84/6/13	E4069801303-0	20	T-4	O	
115	35	85/4/5	8J5040001353-A	10	T-5	K E	T4001C

Fig. 2. Landsat CCT coverage list for a 1/25,000 map area.

4. Conversion of Map Coordinates of Map Corners to Image Coordinates

A. Georeferencing of Landsat-2 and 3 Precision Processed MSS

Landsat-2 and 3 precision processed CCTs projected in Hotine Oblique Mercator(HOM) or the Universal Transverse Mercator(UTM) projection allow the geographical registration of each picture element of the image to their rectangular grids. Accurate interpolation within the image can be used to register each picture element to the HOM coordinate(U, V) or UTM coordinate(N, E) schemes since the HOM or UTM tick marks on the CCT provide the basis for the projection of a rectangular grid onto the image. These HOM or UTM coordinates can be then transformed to latitude and longitude to geoencode each picture element.

The software reads the tick mark information from the annotation record of Landsat CCT and transforms the geographic coordinates(latitude and longitude) of any point in the image to picture element coordinates (line and column) in the images.

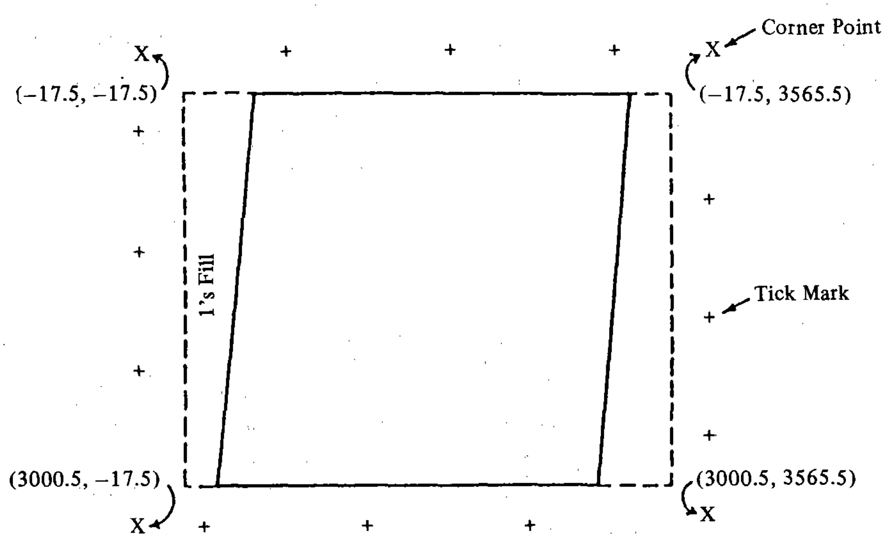


Fig. 3. GEOREFERENCING OF A LANDSAT-2 AND 3 PRECISION PROCESSED IMAGE. The UTM or HOM tick mark information in the annotation record of the CCT provide the map projection coordinates (N, E) for UTM and (U, V) for HOM and the image coordinates (line and column number) for all the tick marks. These data are used to calculate the map projection coordinates for the specific lines and columns containing the four corner reference tick marks of the image whose image coordinates (line and column number) are already known. Using the known line and column number and rectangular map projection coordinates of the four corners, bilinear interpolation is used to calculate either the rectangular map projection coordinates or image grid coordinates of any point in the image.

The first step in converting latitude and longitude to line and column numbers in a Landsat CCT involves calculating the rectangular coordinates(U, V) or (N, E) at the intersection of the line and column locations designating the tick mark locations of the image. The top tick marks are contained in line −17.5, the bottom tick marks in line 3000.5, the left tick marks in column −17.5, and the right tick marks in column 3565.5(Figure 3). The input latitude and longitude entered by the user or user program are converted to rectangular (U, V) or (N, E) coordinates with the appropriate equations(Synder, 1982). Bilinear interpolation is next used to calculate either the rectangular map projection coordinates or image coordinates of any point within the image using the known line and column number and corresponding rectangular coordinates of the four corners. The geographic location of an image map to be extracted from Landsat-2 and 3 precision processed MSS images can be determined by converting the geographic coordinates (longitude and latitude) of 4 desired image map corners to image picture element coordinates (line and column).

B. Georeferencing Landsat-4 and 5 MSS and TM Images

The standard map projection applied to Landsat-4 and 5 MSS and TM images is the Space Oblique Mercator(SOM). The Universal Transverse Mercator(UTM) and Polar Stereographic(PS) map projections are available upon special request, with the PS being available only for areas above 65 degrees north latitude and below 65 degrees south latitude.

Transforming geographic coordinates(latitude and longitude) to image coordinates(line and column) in a Landsat-4 and 5 CCTs also involves two sequential transformation processes. The geographic coordinates are first converted to rectangular map projection coordinates and then the rectangular map projection coordinates are converted to image coordinates. Transforming geographic coordinates to map projection coordinates can be accomplished by the appropriate equations(Snyder, 1982).

The rectangular map projection grid and the image grid of Landsat-4 and 5 CCTs can be described by two overlaid raster grid systems with a relative orientation angle of θ at the WRS scene center(Figure 4). The angle of rotation between the two grid systems, and the coordinates of one location in both grid systems, are necessary to perform a translation from map projection grid to the image grid. These values are contained in the header record of a Landsat-4 and 5 MSS CCTs and in the ancillary record of a Landsat-4 and 5 TM CCTs and consist of:

- identification of the map projection used,
- orientation angle of the map projection,
- WRS(World Reference System) scene center,

- latitude and longitude of scene center, and
- WRS picture element offset from scene center.

Thus, the geographic location (ϕ, λ) can be transformed to image coordinates (r, c) using the simple translation equations of (Thormodsgard and Devries, 1983)

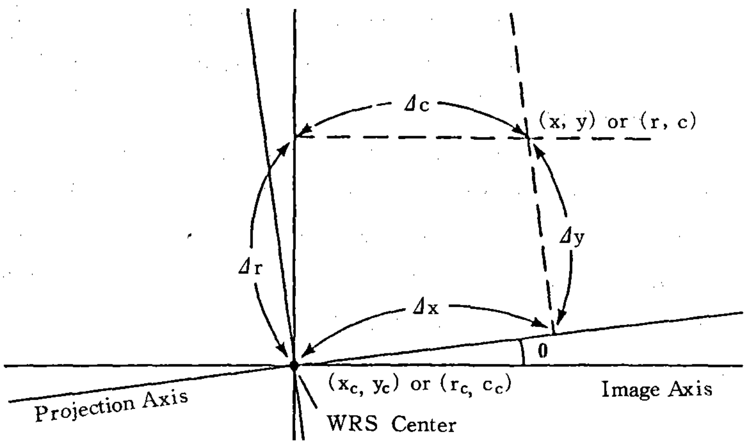


Fig. 4. GEOREFERENCING A LANDSAT-4 AND 5 IMAGE TO A MAP PROJECTION. The rectangular map projection grid (projection axis) and the image grid (image axis) of Landsat-4 and 5 CCTs can be described as two raster grid systems overlaying each other with an orientation angle θ at the WRS scene center. This angle and the coordinates of one location in both grid systems allow user to convert map projection coordinates to image coordinates. Subsequent transformation of geographic coordinates (latitude and longitude) to map projection coordinates can be performed with simple mathematical functions.

$$\Delta c = \Delta x \cos\theta - \Delta y \sin\theta,$$
$$\Delta r = \Delta x \sin\theta + \Delta y \cos\theta,$$
$$c = c_c + \Delta c/\text{picture element size},$$
$$r = r_c - \Delta r/\text{picture element size}, \quad \cdots\cdots (1)$$

where:

θ	=	inclined angle
x, y	=	Cartesian coordinates of projection coordinates
r_c, c_c	=	line and column picture element number of WRS scene center
r, c	=	line and column number of geographic location (ϕ, λ)
Δx, Δy	=	displacement in projection coordinates (meters) between (ϕ, λ) and (r_c, c_c), and
Δr, Δc	=	displacement in image coordinates between (ϕ, λ) and (r_c, c_c).

5. Extraction of Map Area

Unfortunately, map equivalent areas extracted from Landsat CCTs do not exactly match the actual map area desired due to the inaccuracy in geoencoding of the original precision processed Landsat CCTs. The mislocation of the georeferencing of the average scene, and thus the equivalent map area extracted from it, is about 15 picture elements north/south and/or east/west with a variation of about 1 to 30 cells (Miller et al., 1983). Extracting the desired equivalent map area requires putting an additional band of picture elements all around the nominal area. This oversized or "nominal" image map has a high probability of containing the actual map area or image map within its boundary. The specific, calibrated image map area is then located, georeferenced, and trimmed out of the nominal image map.

6. Rotation of Image during Extraction

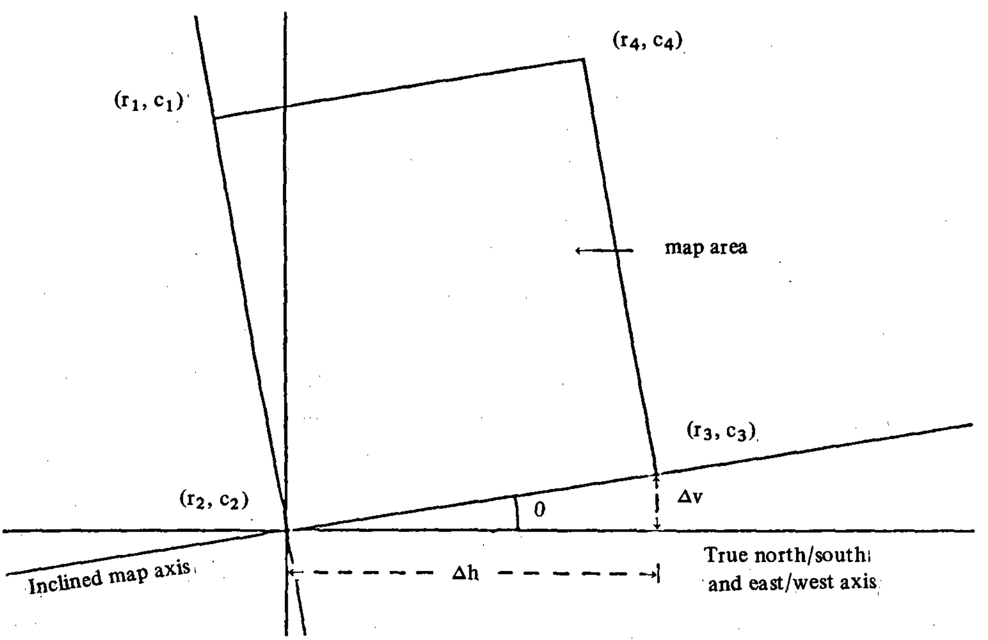
Landsat satellite images are projected to one of the existing map projections(e.g. UTM, SOM, etc.) before they are distributed to the public. These map projections are associated with a grid that is rotated through the satellite heading angle, which is a function of orbit inclination ($\sim 11°$ for Landsat) and scene latitude. The utility of these inclined images for mensuration, precise location, spatial/temporal registration, etc. is therefore limited. The current trend of merging most earth resource data into one large multivariable geoinformation system data base requires this inclined image map be rotated to the true north/south orientation to represent the actual topo map projection(e.g. along Northings and Eastings in the case of UTM). This requires the determination of the actual rotation angle between the inclined precision processed image's grid and the true north/south grid. The rotation angle represents the current satellite heading angle for that scene and changes from scene to scene due to the satellite drift and the associated orbit adjustments made to bring the satellite back to its optimal orbit(i.e. station keeping).

A. Computing Rotation Angle

The computed locations of the selected nominal image map's 4 corners in line numbers and column numbers are used to compute the appropriate rotation angle(Figure 5). The four corners of map area are specified in line and column numbers(r, c) on the top of the two associated grid axis where the original image(Landsat CCT) is inclined. The angle of this axis, the orbit angle θ. is easily computed by the equation.

$$= \text{ARC TAN} \left(\frac{r_3 - r_2}{c_3 - c_2} \right) \quad (2)$$

where, c_2: column number of lower-left corner of image,
c_3: column number of lower-right corner of image,
r_2 : line number of lower-left corner image, and
r_3: line number of lower-right corner of image.



$$\theta = \text{ARC TAN} \left(\frac{\Delta v}{\Delta h} \right)$$
$$\Delta V = r_3 - r_2$$
$$\Delta h = c_3 - c_2$$

where: c_2: column number of lower-left corner of image map,
c_3: column number of lower-right corner of image map,
r_2 : line number of lower-left corner of image map, and
r_3: line number of lower-right corner of image map.

Fig. 5. REFERENCING A MAP AREA EXTRACTED FROM LANDSAT TO A NORTH/SOUTH AND EAST/WEST GRID. Landsat precision processed images are projected with one of the map projection schemes. This map projection grid is inclined to the true north/south and east/west grid with rotation angle θ due to the Landsat satellite heading angle ($\sim 11^\circ$). The rotation angle θ can be computed with Δh and Δv.

B. Resampling of the Inclined Image to N/S and E/W Grid

Resampling techniques proposed for geometric Landsat image transformation include the bilinear and cubic convolution, nearest neighbor, and various truncated versions of (sine x)/x (Moik, 1980). The cubic convolution function renders high quality resampled image maps for typical Landsat images but takes many hours with microcomputer due to its intensive use of floating point computations. The Nearest Neighbor(NN) resampling scheme offers relatively fast operation, thanks to its considerably reduced use of floating point operations, compared to the other methods. The NN approach consists of assigning the value of each picture element or cell in the new, rotated grid to equal that of the picture element or cell closest to it in the original, inclined grid. Computation of coordinates to resample any picture element in map area can be performed by applying the following equation once the rotation angle is determined(Foley and Van Dam, 1983).

$$x' = x\cos\theta + y\sin\theta$$
$$y' = -x\sin\theta + y\cos\theta \qquad (3)$$

where, x, y: column number and line number of a picture element in image or raster in the true north/south and east/west map grid, and

x', y': column number and line number of corresponding picture element in image or raster in the inclined map grid.

Using Equation 3, the coordinates for resampling of all the picture elements in a image map can be computed.

7. Conclusion

The image map extraction process described thus far is essentially automatic and the only required user actions are:

- the entry of the map and state name from a topo map index,
- the selection and mounting of the Landsat CCT,
- the designation of whether to display the image map on the screen or record it on a floppy disk.

The full process involving the map selection and completion of the single band display or multi-band floppy disk TM file takes, on the average, 30 and 60 minutes respectively for an TM digital

References

Foley, J. D., and A. Van Dam, 1983. *Fundamentals of interactive computer graphics.* Addison-Wesley Publishing Co., Reading, MA. 664 p.

Miller, L. D., Y. K. Yang, T. D. Cheng, M. Unverferth, and M. G. Kim, 1983. 7-1/2 image map extraction from precision processed Landsat Multispectral Scanner(MSS) and Thematic Mapper(TM) imagery using a microcomputer and EROS computer compatible tapes. *In Proc. of the Symposium on Techniques for Extraction of Information from Remotely Sensed Images.* SPIE, Rochesters, NY. 15 p.

Moik, J. G., 1980. *Digital processing of remotely sensed images.* NASA SP-431, 330 p.

Snyder, J. P., 1982. *Map projection used by the U. S. Geological Survey.* USGS Bulletin 1532, U. S. Government Printing Office, Washington D. C.

Soil Conservation Society of America, 1982. *Remote Sensing for resource management,* eds. C. Johannsen and J. Sanders. Ankeny, IA. 665 p.

Thormodsgard, J. M., and D. J. Devries, 1983. Geodetic accuracy of Landsat-4 Multispectral Scanner and Thematic Mapper data. *In Proc. of Landsat-4 Scientific Characterization Early Results Symposium.* NASA/GSFC, Greenbelt MD, 15 p.

U. S. Geological Suvey, 1981. *Manual on characteristic of Landsat computer compatible tapes produced by the EROS Data Center digital image processing system.* EROS Data Center, Sioux Falls, SD. 70 p.