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Landscape Drawing from Landsat MSS Data

Landsat MSS data and a digital terrain model are combined to generate the landscape.

INTRODUCTION

PICTURES AND PHOTOGRAPHS have been two major means to present landscape. Pictures have been drawn since the human being appeared on the Earth, and the photographic technique started about 140 years ago. Pictures are drawn by going to a site and grasping a landscape in one's mind. The landscape is then expressed as a drawing. On the other hand, photographs are made by going to a site and then simply by activating the shutter of a camera. Although there exist differences between the two procedures, there is no difference in the sense that one must go to the spot in order to face the landscape. The authors, in this work, were interested in obtaining the landscape without going to the spot. With this in mind, research began to generate a landscape drawing from Landsat MSS data.

KEY WORDS: **Central projection; Digital terrain model; Japan; Landsat; Landscape drawing; MSS**
ABSTRACT: A method to produce a landscape drawing from Landsat MSS data and the evaluation of the landscape drawing, along with an example, are addressed. Landscape drawing from Landsat MSS data is mathematically performed by using the central projection method. The major interest of the authors was to compare the landscape drawing performed by such a method with the same landscape as viewed from the ground. In order to clarify this point, a landscape drawing of Mt. Fuji, one of the typical mountains in Japan, was produced and compared with pictures and photographs of it. The result of the work shows that the landscape drawing from Landsat MSS data is better than one might have expected.
REFERENCE: Tanaka, Sotaro, and Suga, Yuzo, "Landscape Drawing from Landsat MSS Data," *Photogrammetric Engineering and Remote Sensing*, Journal of the American Society of Photogrammetry, ASP, Vol. 45, No. AP9, October, 1979

Before starting this research, the authors discussed, though it is not easy to estimate the demand for landscape drawings in terms of their economic value, how necessary it is to obtain the landscape for human beings as follows.

People enjoy beautiful landscapes. They want to possess a house with a beautiful landscape as its background, and they like to travel in search of beautiful places and take pleasure later in looking at the photographs taken at that time.

It is important for geographers or architects to analyze landscape because, for them, landscape is considered as a fundamental item equal to or more essential than geology, topography, and climate in the investigation of natural conditions in order to ascertain adequency of an architectural planning. For example, the assessment of landscape becomes especially important in land-use planning for recreation. Therefore, three properties of landscape—natural quality, aesthetic quality, and functional quality—are discussed.

Thus, the landscape is a necessity for both ordinary and professional, and having the needs in grasping the landscape, they often have to wait for a favorable season and fine weather with patience. Consequently, the authors felt that a new and easier means to obtain the landscape, e.g., from Landsat MSS data, might find general acceptance both with ordinary people and with experts.

METHOD OF LANDSCAPE DRAWING

IN GENERAL, in order to generate a landscape by computer, two types of data are required, i.e., color (or spectral) data and

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topographic data. In generating a landscape from Landsat MSS data, a set of four MSS band values for each pixel serves as the color data and a digital terrain model (DTM), that is, a set of row and column numbers matching each pixel with its corresponding elevation serves as the topographic data. The two types of data can then be converted into a landscape drawing by means of mathematical procedures. Figure 1 shows the general flow of Landsat landscape generation.

PROCEDURE 1: DETERMINATION OF THE LANDSCAPE VIEW POINT AND EXTENT

First, determine from where and over what extent one is to view the Landsat scene. Mathematically, the coordinates of the view point are designated ϕ_0, λ_0, and H_0, i.e., the latitude, longitude, and elevation, respectively. The center of the extent of the landscape is given by ϕ_c and λ_c, as shown in Figure 2. In fact, these coordinates can be determined from a 1:50,000 scale topographic map of the region. The elevation, H_0, is usually given a value higher than that of the landscape.

Second, after selecting both side lengths by regarding the shape of the landscape as a rectangular, the lateral (side-to-side) extent of the landscape is set normal to the direction between the view point and the center of the landscape. In the computer processing, geographic coordinates (ϕ_0, λ_0) and (ϕ_c, λ_c) are transformed to orthogonal coordinates (X_0, Y_0) and (X_c, Y_c), expressed in a system such as Universal Transverse Mercotor (UTM), by utilizing equations such as

$$(X_0, Y_0) = F(\phi_0, \lambda_0)$$
$$(X_c, Y_c) = F(\phi_c, \lambda_c) \qquad (1)$$

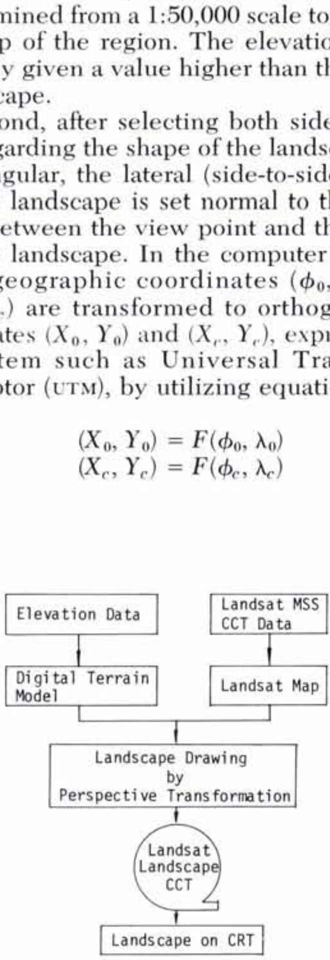

FIG. 1. Concept of Landsat landscape generation.

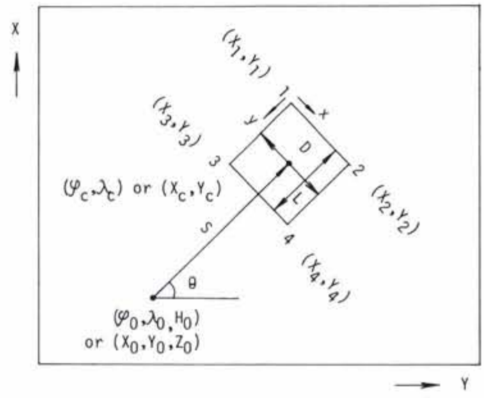

FIG. 2. View point and landscape extent.

where the function, F, refers to the selected projection (e.g., UTM, Gauss-Krüger, etc.). Next, the coordinates of the four corners of the landscape can be determined from

$$X_i = X_c \pm (d \sin\theta)/2 \pm (l \cos\theta)/2$$
$$Y_i = Y_c \pm (d \cos\theta)/2 \pm (l \sin\theta)/2 \qquad (2)$$
$$(i = 1, \ldots, 4)$$

where l is the depth of the landscape and d is the width of the landscape.

PROCEDURE 2: LANDSAT MAP COMPILATION

The Landsat map of the landscape extent can be produced by resampling the MSS data contained in the landscape extent decided upon in the above procedure. Landsat map is a temporary term used by the authors to designate the data resampled such that they can be superimposed completely upon the designated location on the topographic map.

In order to make a Landsat map, an orientation of raw Landsat imagery is performed by using the ground control points selected in the first step. The transformation from the coordinates (X, Y) of the ground control point to the coordinates (x, y) of the raw Landsat imagery, i.e., to a pair of numbers (pixel number, line number), can be made by the affine transformation,

$$x = a_1 X + b_1 Y + c_1$$
$$y = a_2 X + b_2 Y + c_2 \qquad (3)$$

Although this relationship can be determined from a minimum of three ground control points, the coefficients were computed by least squares using six points or more. The transformation accuracy of the pair of equations is high for a narrow field. For example, for a 30 by 30-km square area, the actual positioning errors come within 40 m. This seems good enough for the purpose of landscape generation.

Then, Equation 3, are employed to calculate coordinates of the four corners, x_i and y_i, $(i = 1, \ldots, 4)$ on the Landsat imagery corresponding to the same coordinates, X_i, and Y_i, $(i = 1, \ldots, 4)$ on the ground.

By resampling the pixel data in the area of the landscape scene enclosed by the four corners on the raw Landsat MSS data scene, new MSS data of the landscape extent can be obtained. Among resampling techniques, the nearest neighbor method is adopted here by the authors. The interval of resampled pixels is arbitrary. However, good results would be obtained by using 50-m interval.

PROCEDURE 3: CONSTRUCTION OF DTM

The elevation values for the resampled data can be provided by several means, e.g., from topographic maps or photogrammetrically. In the experiment, contour lines were digitized from a topographic map and the elevation data at designated matrix points were interpolated from the contours.

A second order polynomial of the form

$$Z = F(x, y) = a_1x^2 + a_2y^2 + a_3xy + a_4x + a_5y + a_6 \quad (4)$$

was used for the interpolation.

In order to obtain the coefficients of Equation 4, the authors used at least 13 control points, although 6 points would have been enough. Control points for the surface fitting were chosen so as to fall within the smallest circle around the observation point including 13 points or more, as shown in Figure 3. Thus, the coefficients of Equation 4 can be obtained by solving by least squares the simultaneous equations formed for the 13 or more points. In addition, the authors gave each equation a weight which is inversely proportional to the distance between an observation matrix point and each control point.

PROCEDURE 4: PERSPECTIVE DRAWING

By combining a DTM with the corresponding Landsat map obtained as mentioned above, a Landsat landscape drawing can be produced by employing a perspective transformation. First, it is necessary to establish the background color of the Landsat landscape. This can be done in a computer process by setting the same values for all MSS pixels in the picture. For example, setting appropriate digits to Band 4 and assigning blue light to the Band, the final landscape drawing can have a blue color for the sky.

The next step is to compute a series of coordinates for the sky line on the perspective plane, that is, the profile of the ground surface, by joining the DTM stored in the disk memory to the MSS data of the Landsat map.

The coefficients of the linear perspective are determined by a proportional computation as shown in Figure 4. A series of coordinates in the perspective plane corresponding to each skyline are then computed and, finally, the MSS data of full lines are distributed on the perspective plane, that is, the pixel contents are allocated to each position assigned on the perspective plane coordinate system.

In this case, the computation is carried out so that the projected area of a pixel could be enlarged in proportion to the distance between the pixel and the view point. The skyline drawing must be made in order from the farthest edge to the site of the view point.

AN EXAMPLE OF LANDSCAPE GENERATION

CHOICE OF STUDY AREA

Mt. Fuji, located about 100 km west of Tokyo, was selected as the study area for this work. A famous wood block printer, Katsushika Hokusai, was fond of the land-

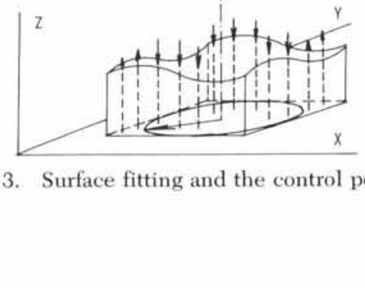

FIG. 3. Surface fitting and the control points.

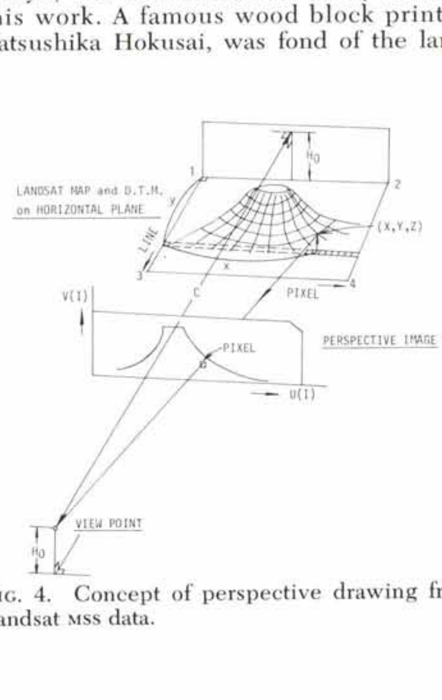

FIG. 4. Concept of perspective drawing from Landsat MSS data.

scape of Mt. Fuji. He made 36 wood block prints of the mountain, each from a different view point. These are now the most familiar prints in Japan. The authors aimed to generate these same 36 views of Mt. Fuji by utilizing Landsat data.

Figure 5 shows the location of Mt. Fuji and indicates some of the spots from which it can be seen. The two pictures shown in Plate 1, which are titled "The Red Fuji" and "The Coast of Tago", respectively, are the most popular of the Thirty-six Views of Mt. Fuji by Hokusai.

Incidentally, it is worth noting that the present site of Mt. Fuji has changed considerably from what it was during the days of Katsushika Hokusai. One of the busiest roads in Japan, that linking Tokyo to Kyoto, passes very near Mt. Fuji. Moreover, the new Tokaodo high-speed railroad line passes along the southern skirt of Mt. Fuji. This area is regarded as one of the favorite National Parks in Japan.

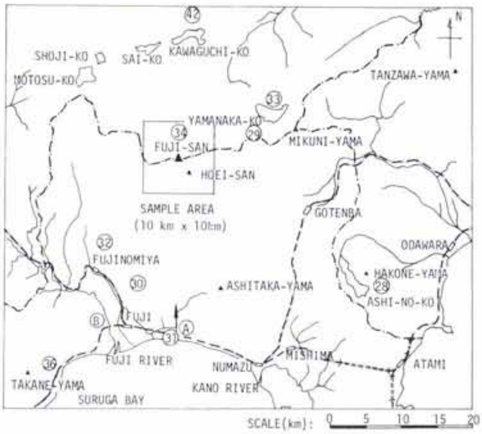

FIG. 5. Location of study area and view points.

LANDSAT MAP AROUND MT. FUJI

Landsat MSS data, ID No. E-1145-00542-502, acquired on December 15, 1972, was utilized for the experiment. The landscape drawing generated by this experiment was configured such that the center of Mt. Fuji could be viewed horizontally from a spot 30 km due south at an elevation of 1500 m. The extent of the landscape was such that it covered a 10 km square. The coordinates of the four corners are listed in Table 1. In the table, the values are expressed both by coordinates in Zone No. 8 of the Plane Rectangular Coordinate System of Japan and by coordinates (pixel number, line number) in the Landsat imagery coordinate system. The linear relationship between these coordinates in this scene was established by using the eight control points listed in Table 2.

After selecting the coordinates of the four corners of the landscape extent in the Landsat imagery coordinate system, MSS pixels contained in the landscape were resampled from the raw Landsat MSS data and stored in new rectangular matrix points. The dimensions of the new matrix points, 200 pixels by 200 lines, was obtained by dividing the 10 km side lengths into a 50-m interval. The set of the resampled MSS data was designated as the Landsat map around Mt. Fuji. Its color composite image was made up of the following combination: MSS 4 to blue, MSS 5 to green, and MSS 7 to red, as shown in Plate 2.

DTM AROUND MT. FUJI

The value of the elevation corresponding to each pixel in a Landsat map, that is, the original data for the digital terrain model around Mt. Fuji, was obtained by digitizing a series of points along each 100m contour line. The data sampling was carried out in a mode in which the sampling ratio was determined by a designated time interval. In this sampling mode, the distance interval between points comes to about 2 to 3 mm in actual length on the tracing table. However, if any adjacent points are more than 5 mm apart, they are checked out as inappropriate. Figure 6 shows the sampled contour lines as they appear on a graphic display unit. The square around Mt. Fuji is the landscape extent, equal to the area corresponding to the above Landsat map. The four corner positions of the landscape were given in the Japanese coordinate system, and those coor-

TABLE 1. CORNER COORDINATES OF LANDSAT MAP AROUND MT. FUJI

Corner No.	Ground Position latitude	Ground Position longitude	Ground Position* X(m)	Ground Position* Y(m)	Landsat 1 pixel	Landsat 1 line
1	35°24′16″.1	138°40′36″.2	−66047.9	16049.3	444.4	269.9
2	35°24′16″.1	138°47′14″.2	−66024.3	26089.6	614.1	246.5
3	35°18′51″.9	138°40′36″.2	−76037.2	16067.1	487.5	392.0
4	35°18′51″.9	138°47′14″.2	−76013.7	26118.6	657.5	368.5

* Plane Rectangular Coordinate System of Japan (Zone No. 8)

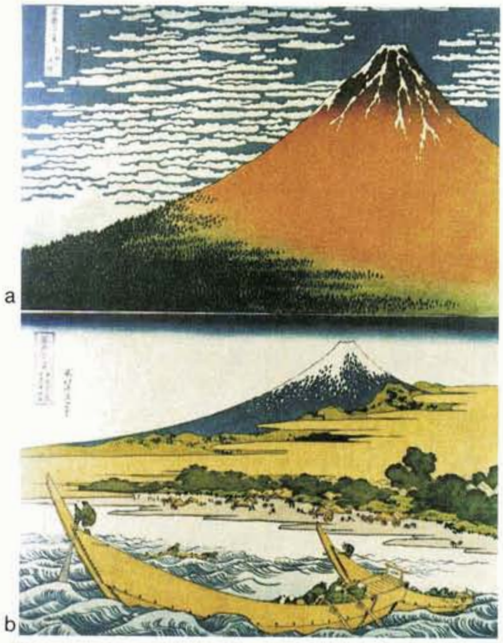

PLATE 1

PLATE 2

PLATE 3

PLATE 4

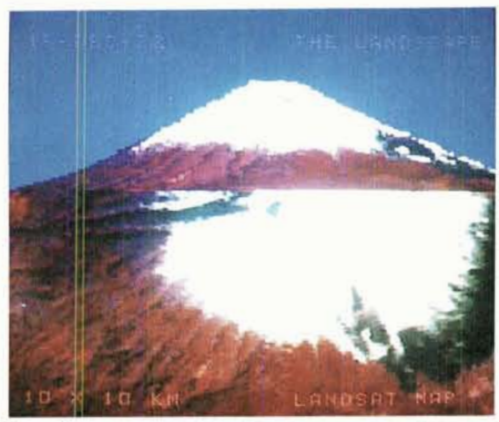

PLATE 5

PLATE 6

PLATE 1. The Thirty-six Views of Mount Fuji by Hokusai. (a) View point 33, (b) View point 36.
PLATE 2. Landsat Map of Mt. Fuji area.
PLATE 3. Landscape by Landsat MSS data (View point A).
PLATE 4. Ground photo (view point B).
PLATE 5. Combination of landscape and Landsat Map.
PLATE 6. One of the Thirty-six Views of Mt. Fuji (view point 31).

TABLE 2. GROUND CONTROL POINTS

No. GCP Name	Ground Position latitude	longitude
1. Nakamura	36°35′35″.8	138°11′58″.6
2. Kobushi-ko	35°36′30″.2	137°59′27″.1
3. Onuma	36°32′56″.8	139°11′16″.1
4. Kawaguchi-ko	35°30′40″.1	138°44′49″.9
5. Tagonoura	35°08′17″.9	138°42′00″.0
6. Yokota	35°45′00″.0	139°21′01″.5
7. Shiojiri	36°06′56″.8	137°57′46″.0
8. Enoshima	35°17′44″.7	139°29′28″.9

dinates were then converted into the machine coordinate system of the digitizer. A series of elevation points along the contour lines were then transformed into the DTM corresponding to the Landsat map. The matrix size of the terrain model comes to 200 pixels by 200 lines. By comparing the data at each matrix point with the corresponding elevation value on the topographic map, the interpolation accuracy (standard deviation) was found to be about 30 m.

A LANDSAT DRAWING OF MT. FUJI

Using both the Landsat map of the Mt. Fuji area and the corresponding matrix DTM obtained above, a landscape drawing was generated. The picture size was specified as 200 pixels by 200 lines in order to fit the size of the above Landsat map. Its background color was assigned as blue and for this, a value of 64 was set in the Band 4 memories at the beginning of the perspective transformation. The final perspective transformation was performed against this blue background, line by line from the farthest point to the view point.

FIG. 6. Terrain points by digitizer.

CONCLUSION

Plate 3 shows the result of the Landsat landscape drawing displayed on the CRT of a GE Image-100. The perspective is the one viewed horizontally toward the center of Mt. Fuji from the spot A shown in Figure 5, whose position (35°08′N, 138°44′E) is about 30 km due south of Mt. Fuji at an elevation of 1500 m.

The Landsat landscape drawing is not as detailed as the ground photograph of Mt. Fuji (Plate 4). However, it is certainly recognizable as a view of Mt. Fuji.

Plate 5 shows the same Landsat landscape displayed in a different manner on the CRT of the Image-100. In the upper half appears the Landsat landscape and in the lower half, the Landsat map. One of the merits of this display is that it shows the landscape environment both planimetrically and spatially. Plate 6 shows one of Hokusai's Thirty-six Views of Mt. Fuji as viewed from almost the same spot as view point A. We can now confirm the credibility of the wood block print of Mt. Fuji from the landscape drawing shown in Plate 3.

The Landsat landscape drawing generated from the MSS data from Landsats 1 and 2, whose pixel size is 57 by 79 m has the appearance of a rather coarse oil painting. Finer Landsat landscape drawing will be possible as the resolution of Landsat MSS data improves. The authors plan, sometime in the future, to draw landscapes of the Moon and Mars by using this same method.

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2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
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