Automatic Road Selection from LANDSAT Data

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Commission VII

1 INTRODUCTION

Recently in addition to remote sensing tecniques,the computer-aided Geo-information System (GIS) has been recognized to be effective and utilized to prepare basic data for decision making in administration and policy control by integrating various data of topographical and geological features, land use,etc. As for traffic policies, when a road is designed, (1) natural conditions (2) society and culture, (3) geographical environment, etc . are comprehensively investigated in the initial stage with a wide view. The labor, cost and time spent for the investigation are enormous. If the GIS system by use of micro computer is used for it, time and cost can be remarkably saved. Papers published hitherto deal with how to establish condition for designing a road route by overlaying various data required for route setting, and few papers refer to automatic setting of road route. This report describes a topographical recognition system based on the altitude data of land numerical information, and also the automatic design of road routes by use of various overlaid pieces of information such as development regulation data and by use of a micro computer rapidly developing of late. Furthermore, the designed results are discussed to compare the respective routes in reference to topographical sectional area and slope.

2 PREPROCESSING OF DATA

Various data required for GIS were preprocessed as follows, in order to be processed by the micro computer. Block diagram of data preprossing is shown in Fig . 1.

1) The altitude data of land numerical information was transferred from the magnetic tape to an 8-inch floppy disk, to make an altitude data base.

2) A development regulation map on a scale of one to fifty thousand was sectioned into 250 m meshes and recorded into an 8-inch floppy disk by a digitizer, to make a development regulation data base. The respective classified zones were coded and recorded.

3) A land use map on a scale of one to fifty thousand was sectioned into 250 m meshes and recorded into an 8-inch floppy disk by a digitizer, to make a land use data

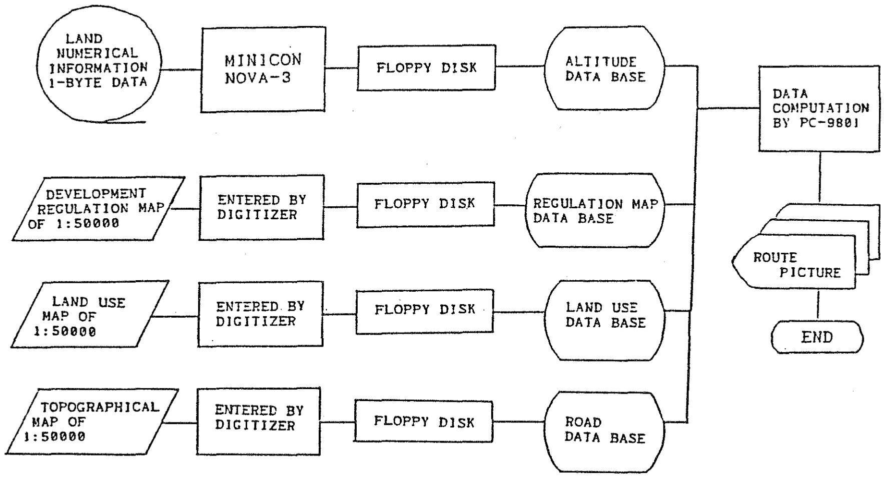


Figure 1: Block diagram of data preprocessing

base. The land use map was classified into five major zone types.

4) The district selected for the investigation was a hilly district in the south of Chiba Prefecture. From four topographical maps drawn on a scale of one to fifty thousand, main national highways were entered by digitizer, and made to correspond to the CRT(400x640 dots) of the micro computer by affine transformation.

5) An artificial topographical map which allowed easy visual discrimination of topographical features was prepared using the altitude data, from the altitude differences.

3 ALGORITHM FOR AUTOMATICALLY DESIGNING THE ROAD

In this study, a topographical recognition system required for road designing was used, to overlay various data, for automatically designing the road.

3.1 Topograhical recognition syatem

Based on the fact that the recognition of topographical features starts from the observation of surrounding conditions,the idea of search as shown in Fig.2 was introduced as a method of topographical recognition.

An aiming line is drawn from a given start point to the intended terminal point, and direction lines are drawn on both sides of the aiming line at 10-degree intervals upto $\pm$ 60 degrees, respectively at a predetermined length of radius R. The sector thus obtained is called a search area.

The data obtained in the respective directions are computed according to a given algorithm, to decide the optimum direction, and a route is drawn in that direction by a unit distance (1 dot).

Then, with the newly set point as the start point, an aiming line is drawn to the terminal point, to make a similar search area again. Then, the optimum direction is decided, and the start point is moved in that direction. thus, this operation is repeated till the terminal point is reached.

For deciding the optimum direction, various algorithems can be considered. In this study, topographical undulations were given priority in route decision, and for this reason, altitude integration was used. Figs. 3 show the principle. If a topographical obstacle exists in a mountainous area, etc. in a search area, the section in the direction lines D1 and D2 are respectively as shown in Figs. 3-b and 3-c. The topographical Features are recognized in reference to the areas of the sections, and the direction smaller in the integral value is selected as the optimum direction. In this case, direction D1 is gentler in slope and less in the volume of earth to be removed, than direction D2 . Therefore, direction D1 is the optimum direction in this case.

If R pieces of altitude data A(Dn,i) are available in ach direction line, the altitude integration S(Dn) is expressed by the following equatio.

$$S(Dn) = \sum_{i=1}^{R} A(Dn, i) \tag{1}$$

where n is the number of the direction line for the search range concerned. If n=13, the search angle is 120 degrees.

The route decision by equation (1) may not satisfy the condition that a road should take the shortest distance to its destination, since priority is given to the evaluation in the search area. To correct the tendency, it is possible to weight the integral values, with a light weight applied to the aiming line and heavier weights to the other direction lines, in order to let the optimum route approsch the aiming line. If this is defined as a distance factor, equation (1) can be converted into equation (2) as shown below.

$$S(Dn) = K(Dn) \sum_{i=1}^{R} A(Dn, i) \tag{2}$$

The distance factor can be divided into a horizontal distance factor and a vertical distance factor. As for the former, if the search area is made to approximate to an isosceles traiangle as shown in Fig.4, and the weight in the aiming line direction is 1, then the weight in the direction at a search angle of ± 60 degrees is 2, and the weight in a given direction is proportional to $\frac{1}{cos}\theta$.

As for the vertical direction, if the altitude difference for a unit mesh distance of di is hi as shown in Fig.5, the vertical distance factor is $(1 + \frac{hi}{di})$. If it is applied as a weight to the altitude integral value S(Dn) in direction Dn, a larger hi value makes the weight for data larger and also S(Dn) larger. Thus, data of gentler slope is selected. In this case, Kn is expressed by the following equation.

$$K(Dn, 1) = \frac{1}{cos}\theta(1 + C\frac{hi}{di}) \tag{3}$$

where if C =0, the distance factor becomes a horizontal weight, K(Dn).

if C =1, the horizontal and vertical weights become equal.

if C =2,3,...., the weight of altitude becomes larger.

The selection of a value for C decides whether the route is set with emphasis placed on undulations or on the shortest distance.

If $C \geq 1$,equation (2) can be converted into equation (3).

$$S(Dn) = K(Dn)\sum_{i=1}^{R} K(Dn, i)A(Dn, i) \quad (4)$$

If C =0, the term K(Dn,i) is fixed to K(Dn), and equation (3) is returned to equation (2).

In this study, C was set at 0 for horizontal weighting, in order to obtain a route of the shortest distance.

4 FLOW DIAGRAM OF PROCESSING BY THE TOPOGRAPHICAL RECOGNITION SYSTEM

Event if the optimum direction is decided in reference to the distance factor and altitude integration,it is desired that the route progresses in the direction of gentle slope.

For this reason, slope check was applied, so that the direction with the gentlest slope may be identified and selected as the route from the start point. In this technique, the altitude integral values S(Dn) for the respective direction lines are arranged in the order of desirability with the optimum direction line at the top,and the percent of slope in the direction to the adjacent dot in the optimum direction is computed. If the value is less than the predetermined percent of slope (5 % in this case), the start point is move in that direction by one dot (approx .250m). If the value is not less than the predetermined percent, similar computation is made for the direction line preferred next. If the direction lines have been found to be 5 % or more, the direction line with the least percent of slope is selected, in extending the route.

Thus the slope check allows always gentle slopes to be obtained in route setting.

Considering the above, the following processing flow was prepared as shown in Fig .6.

5 RESULTS OF PROCESSING AND SIMULATION

In this study, the route was set at first in reference to the altitude integration. To know the effects in the decision of optimum search area and optimum search distance, and in the application of distance factor and slope check respectively, simulation was made for the same area for the following three cases.

Case 1 : Route setting in reference to altitude integration only

Case 2 : Route setting in reference to altitude integration and slope check

Case 3 : Route setting in reference to distance factor weighting, altitude integration and slope check

For the above three cases, routes were set with the search angle set at 20,40,60,80,100 and 120 degrees and with the search length (search area radius) set at 10 dots (2,500 m), 20 dots (5,000 m) and 30 dots (7,500 m) respectively, and their suitability was discussed mainly in reference to the following parameters:

1) Total count corresponding to the horizontal distance to the destination

2) Altitude profile showing the change of altitude along the route and approximate sectional area(total count soil:TCS)

3) Slope profile showing the change of slope along the route and average percent of slope

Case 1 : Figs.7 shows the appropriate parameters of routes for recognizing topographical features in reference to the integral values of altitude data only. As can be seen from the figures, even if the search angle was changed with the search length kept constant, no significant relation was observed between the total count and the TCS value, and the slope profiles showed large undulations in the respective routes. Even if the search length was changed with the search angle kept constant, similar results were obtained. In case 1, no relation was found between the recognition of topographical features and trends in the respective set routes.

Case 2 : Figs.8 shows the results of simulation. Since the slope check was applied, the slope profile became almost constant with undulations kept small, according to the increase in search angle, and furthermore, the total count tended also to decrease. Especially at search angles of 100 and 120 degrees, the average percent of slope was low, being from 2.7 to 4.2 %. Furthermore, the increase in search length tended to make the altitude profile gentle.

Case 3 : In this case all the count values were 90 or less, and it was found that the shortest distance could be obtained by using the distance factor. The altitude profiles and slope profiles showed the same trend as in Case 2. The variation of TCS was also small compared with Case 1 and 2. This case is surmised to provide the most excellent method among three cases.

Generally considering the above results, the seach angle of 120 degrees and the search length of 10 dots (2.5 km) were found to allow the best recognition of topographical features. These values can be used, to draw the route betwwen Hada and Kamogawa.

6 DUAL SEARCH

In general in route setting, it is desirable that when the start point and terminal point are exchanged, the same route is obtained. However, since the topographical features observed from the start point are different from those observed from the terminal point, different recognition and evaluation are naturally made in this topographical recognition method.

Thus, dual serch has been contrived, to start searching simultaneously from the start point and the terminal point, in order to obtain a slope route. The flowchart is the same as that of Fig .6. At first, search is made from the start point toward the terminal point, and the start point is moved in the optimum direction by one dot, to make the second start point. Then, from the terminal point, search is made toward the second start point, and the terminal point is moved by one dot in the optimum direction, to make the second terminal point. Thus, the same search is repeated by turns, and finally at about the middle between the start and terminal points, the route from the start point and the route from the terminal point are connected, to drow one route. In the search made from Hoda to Kamogawa and in the search made from Kamogawa to Hoda, the undulations are remarkable near the terminal point, but in the dual search, they are gentle. The average slpoe in the dual search is large in general, but shows intermediate values between the average slope obtained in the search from Hoda to Kamogawa and that from Kanogawa to Hoda. This is surmised to have been caused since the directions of the two points (start point as terminal point and teminal point as start point) changed alternately.

7 RESULTS OF DATA OVERLAYING

The conceptual view of data overlaying is shown in Fig . 9.

The overlaid data were used for route setting in reference to altitude integration. The results are shown in Fig. In this case, dual search was made with the search length set at 10 dots and the search angle at 120 degrees. The results are shown in Fig .10 .

8 CONCLUSION

In this study, the ideas of search area and altitude integration were proposed for topographical recognition. In this case, it was found that the use of weights and slope check at a search area radius of 10 dots (2.5 km) and a search angle of 120 degrees allowed the topographical features to be recognized best.

With regard to data overlaying, the reason why good results were not obtained in profiles is surmised to have been the execution of data overlaying. However, since data computation was corrected to avoid landslide areas in the data overlaying of this time, the landslide areas could be almost satisfactorily avoided.

In this study, the fundamentals of topographical recognition were established by various parameters. In future, more satisfactory results are intended to be pursued by overlaying with GIS data.

The authors are greatly indebed to Mr . K . Minekawa for helpful discussion and valuabl assistance.

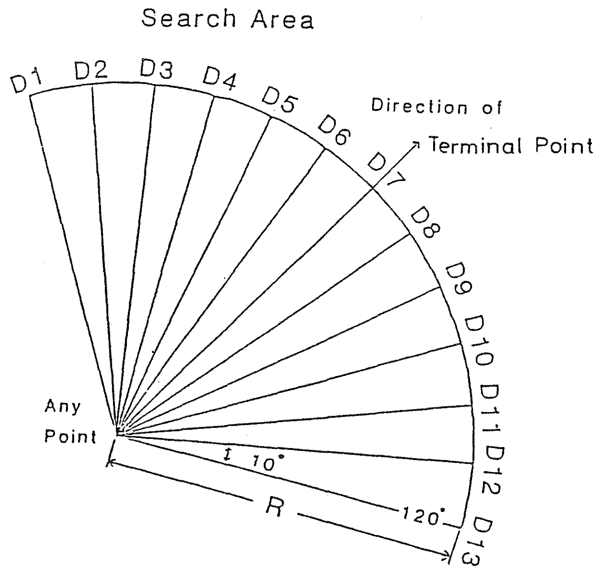


Figure 2: Search area

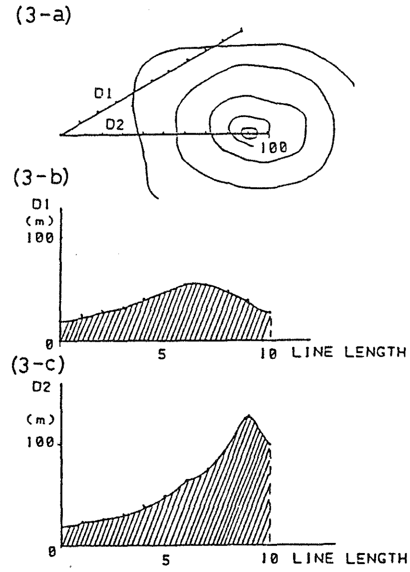
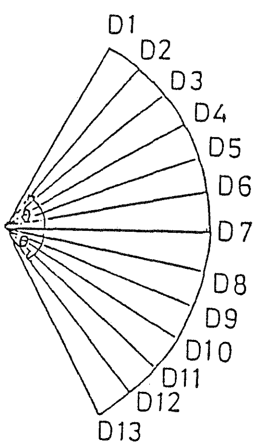


Figure 3: Altitude integration



DIRECTION	DEGREE	K (Dn)
D1	60°	2.00
D2	50°	1.56
D3	40°	1.31
D4	30°	1.15
D5	20°	1.06
D6	10°	1.02
D7	0°	1.00
D8	10°	1.02
D9	20°	1.06
D10	30°	1.15
D11	40°	1.31
D12	50°	1.56
D13	60°	2.00

Figure 4: Weight of each direction

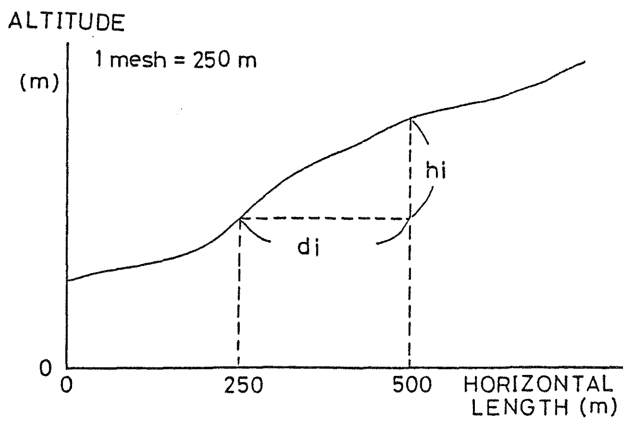


Figure 5: Vertical weight

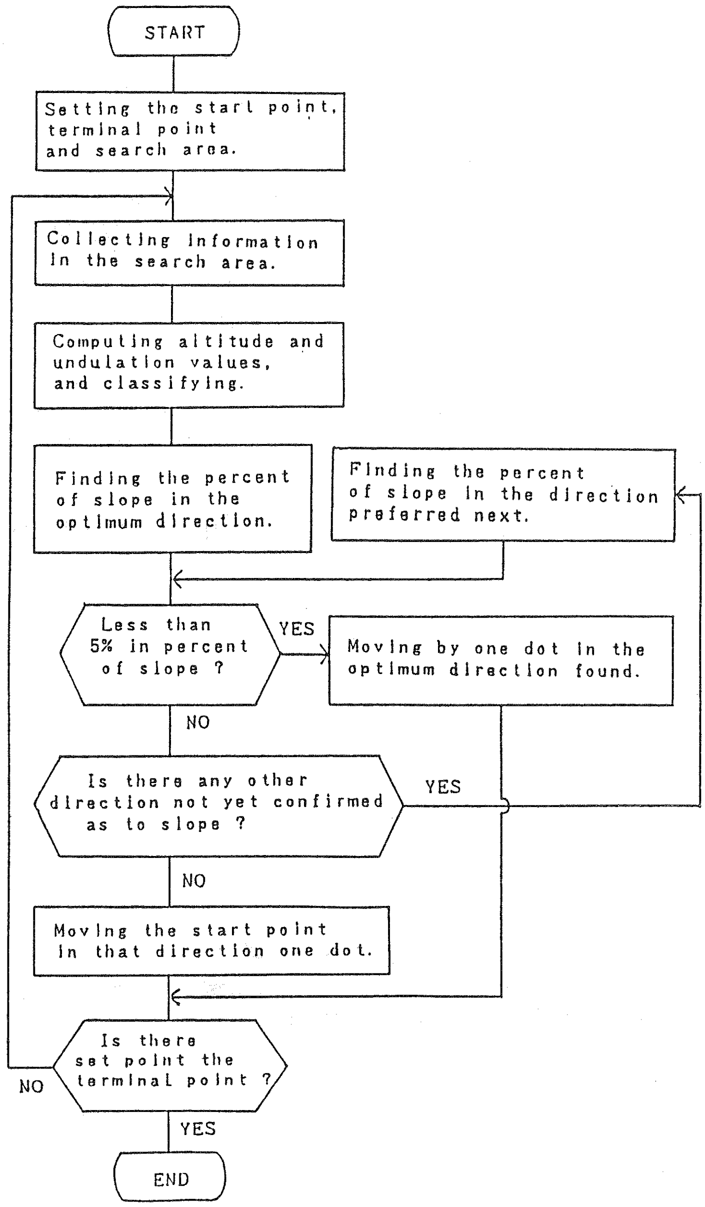


Figure 6: Flowchart of data computation

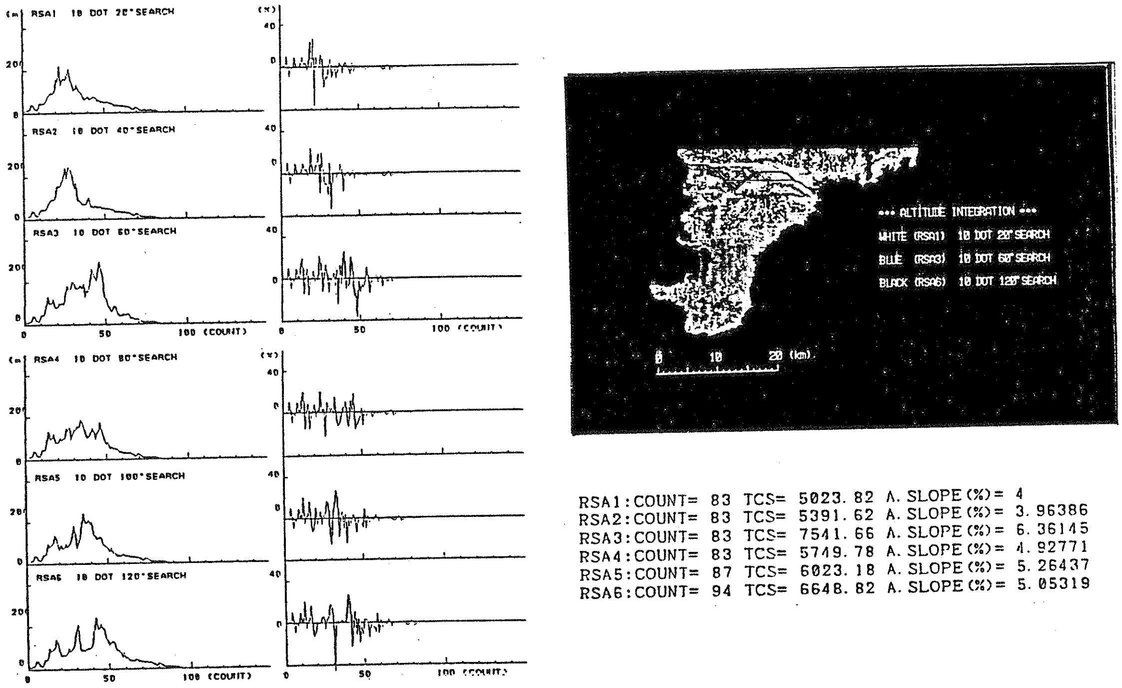


Figure 7: Result of altitude integration 10 dot (about 2 .5 km) search

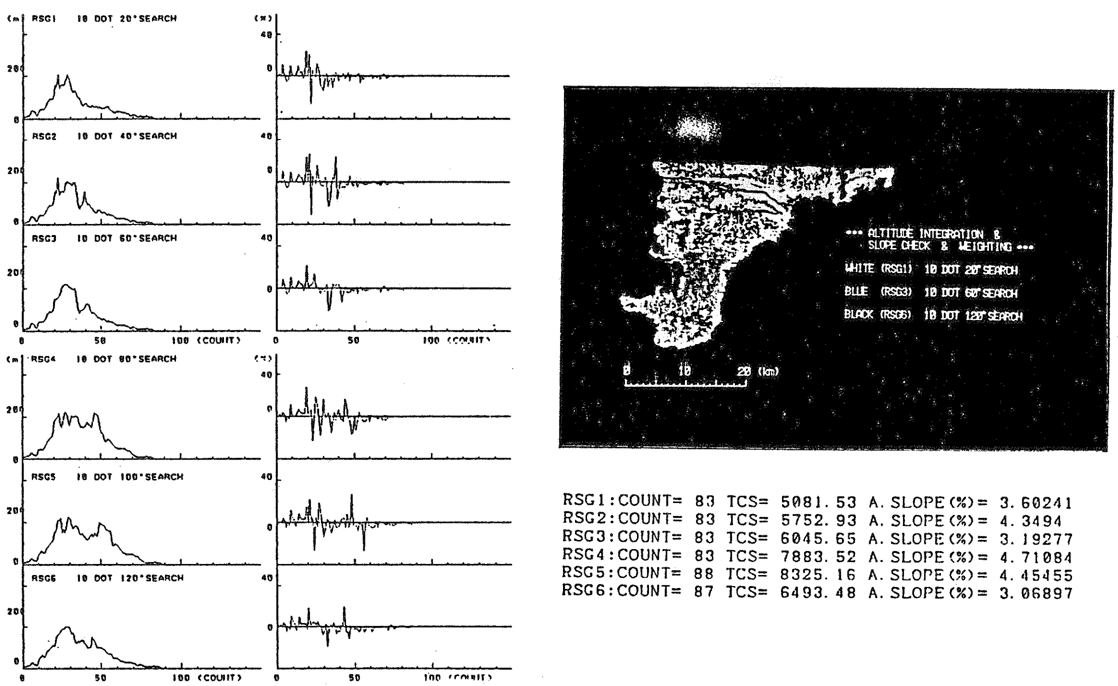


Figure 8: Results of altitude integration and slope check and weighting 10 dot (about 2 .5 km) search

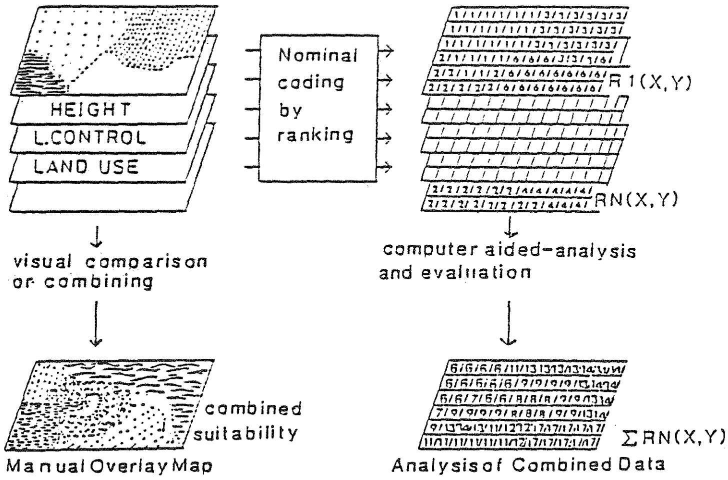


Figure 9: Data overlay

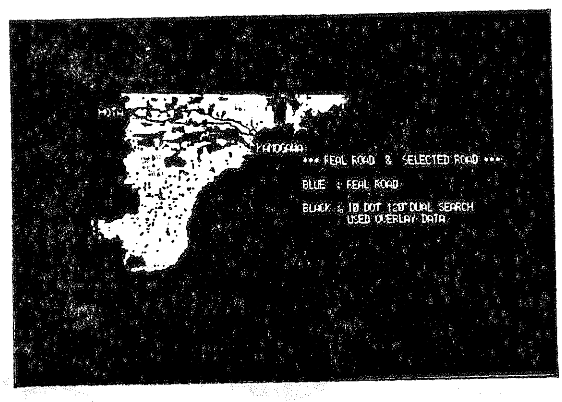


Figure 10: Result on overlay data

Upper : Real road
Lower : Selected road(10 dot 120° dual search)
(on the regulatiom map)

Acknowledgement:

We take this opportunity to acknowledge assistance received from Mr. K. Minekawa and special mention shoud be made of the members of Emori's Lab..