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AUTOMATED HEIGHT INFORMATION ACQUISITION FROM TOPOGRAPHIC MAP

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ABSTRACT

An automated system has been developed to generate grid DTM data from a rasterized topographic map. Conventional methods used are based on either "raster-vector conversion" or "line following" and require a lot of manual input and computing time. The system developed here is based on automated recognition of color contour lines from a rasterized topographic map and automated tracing of the sectional heights of the recognized lines.

KEY WORDS:
HIS, YIQ, Color Separation, RCD, DTM

INTRODUCTION

Extraction of DTM data from existing color topographic maps with contour lines is of great importance to many applications such as landscape analysis, land form classification, civil engineering planning and design, geographic information systems, etc. Existing topographic maps include much noise due to color variation, grid lines, letters and symbols for identifying contour lines. This noise can be eliminated automatically, semi-automatically or interactively by computer.

The present techniques of acquiring DTM data from existing topographic maps are :

(I) Manual following of the contour lines using a digitizing tablet. This is actually a very tedious and monotone operation with a high probability of errors, e.g. by duplicating or omitting information.

(II) Mechanical following of the contour lines using a scanning device. This approach requires a fair amount of computing time to connect the individual segments of lines as well as manual work for assigning the proper elevations. In Japan, two methods have been used; **(1)** Contour Following method for raster output data, and **(2)** Vectorization method for vector output data. However, both of them still require a lot of manual work for assigning the proper height attribute to each contour line.

The objectives of the study are:

(1) To develop an algorithm to separate the contour color from other colors in the topographic map.

(2) To develop an algorithm to automatically trace rasterized contour lines which have been digitized in raster mode by a drum scanner.

(3) To develop an algorithm to automatically assign the contour height to each contour line.

(4) To generate a digital terrain model (DTM) using an interpolation method.

The key algorithms :

(1) color separation

(2) automated tracing

(3) automated height assignment.

Computer software has recently been developed to generate DTMs from Thai and Japanese topographic maps with a scale of 1:50,000.

OUTLINE OF THE PROCEDURES OF THE SYSTEM

The system consists of the following procedures (Fig 1) ;

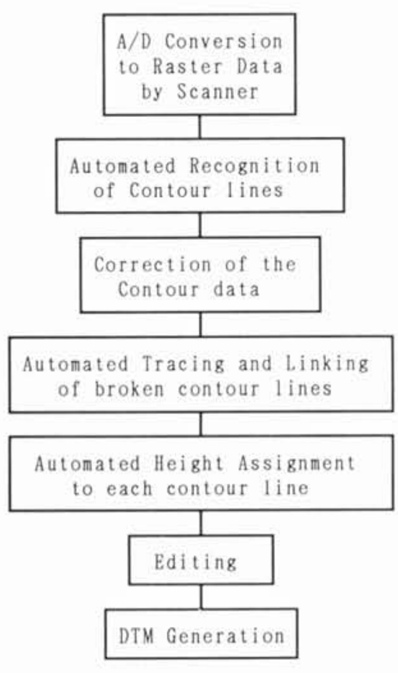

Fig. 1 Flow of the software

A/D Conversion : This involves scanning of a topographic map to generate the color raster image data based on the RGB(Red, Green, Blue) component. The image data still contain the same detailed information as the topographic map.

Automated Recognition of contour lines : This is a process for recognizing only the color which represents the contour lines from the scanned topographic map and to generate rasterized data as input for the height assignment process.

Correction of the input data : After the contour lines have been recognized, some part of the other map symbols are also recognized because of the color distortion especially from the red and black color. These parts of data can be deleted by the short arcs and white noise detecting algorithm. Moreover, some parts a the contour line touch another and, unfortunately, the height numbers of the index contour lines are also being recognized since they have the same color as the contour lines. Therefore, some correction is needed to erase these height numbers and to separate touching contour lines. This correction is performed interactively using a digitizer and a graphic display.

Automated tracing and linking of broken contour lines : Some parts of the recognized contour lines are broken by map symbols which have different colors other than the contour lines. This process is to detect the starting and ending positions of the broken contour lines and to determine the corresponding position for the broken lines. If the corresponding position is found, a linking procedure will be involved.

Automated height assignment to each contour line : The height assignment system is based on a method named "Relief Change Detection" (RCD). The principle of the RCD method is shown in Fig. 2.

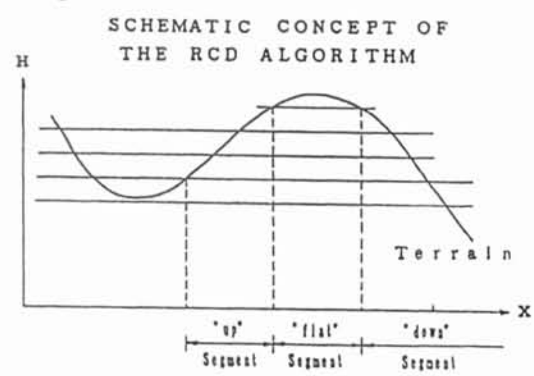

Fig. 2

The following parameters are required to be given interactively to the system :

(a) The position of the relative relief change on a horizontal line.

(b) A height of the contour line at the most left side on this horizontal line.

(c) The position of a relative relief change on a vertical line.

(d) A height of the contour line at the top of this vertical line.

(e) The contour interval.

This system aims to reduce the inputting time and therefore, the number of input lines for the position of the first relative relief change is only two (one horizontal and one vertical).

Editing : More relief change information is usually required by the system if there are any contour heights which the system cannot identify. In such cases, the system will show the positions of unidentifiable height-contour lines on the graphic display and request the user to input the relative relief change information of that part interactively. The user can use the editing function for checking the heights of the contour lines.

The editing process and the inputting of the parameters is made interactively by using the digitizer, the keyboard and the graphic display.

DTM generation : This step involves an interpolation process to generate a grid elevation model (DEM). Since the interpolated heights on the grid point already have been determined, other DTM information (slope gradient, slope aspect of the terrain, and/or hill shading) are being generated at this stage.

KEY ALGORITHMS

The following key algorithms have been tested to generate a DTM from Thai topographic map and Japanese topographic map with a scale of 1:50,000 :

Color separation : In the previous study[5], the color separation is based on the supervised classification on the Hue (H), Saturation (S), and Intensity (I_H) component. It means that the user has to input some training data to the system to determine a range of the threshold. Therefore, the result is really depended on the training data. Practically, it is rather hard to select the good representation training data. In this paper, the adding and subtracting idea was tested. The flow is as follow:

(1) convert from Red(R), Green(G), Blue(B) to Hue(H), Saturation(S), and Intensity(I_H)

(2) convert from Red(R), Green(G), Blue(B) to Y, I_Y, Q[7]

(3) The result image (Im) is performed by :

$$Im = H - I_H - Y - G + R + S + B - (I_Y + Q)^{-1}$$

The result from this idea is almost the same level as the best result of the previous study (Fig.4).

Automated tracing and linking of broken contour lines : As a first requirement, the segment **x** is considered to be a neighbor of the segment **y** if **x** and **y** are considered reasonably close to each other gauged by the distance between their nearest interest points. The second requirement is that the trend of the segment **x** (relative to **y**) should not deviate too much from the alignment of the segment **y**. Thus, the process proceeds in four stages :

(a) Determine the starting and ending positions of the broken contour lines. In this process, the vertex of the contour lines has to be considered.

(b) Collect the neighboring brake position that falls within a designed window around the interest brake position. A searching process is performed to determine the corresponding position for position start to position end, position end to position end, and position start to position start.

(c) Determine the corresponding position based upon the criterion that the angle of deviation between the vectors representing the trends of the two broken contour lines lies within the threshold angle t_a. The angle t_{AB} between the two vectors A and B can be obtained from the equation

$$\cos(t_{AB}) = \frac{A \cdot B}{|A| \cdot |B|}$$

where $A \cdot B$: the (Euclidean) inner product

$|A|$, $|B|$: the (Euclidean) norms of A and B

(d) Linking : If the corresponding position is found, linear linking will be performed from the interest brake position to the corresponding brake position.

Automated height assignment : The height assignment is based on the RCD method, as mention before. RCD is a method for tracing sectional heights on a rasterized contour, line by line scan. A neighboring segment on a scan line is either up, down, or flat in relation to the current height determined from the former segment (Fig.2). The RCD method was developed from the idea that the terrain surface is not always homogeneous, isotropic or linear, as the surface shape is dependent on the local geomorphology. However, a profile of the terrain surface is quite simple because the characteristics of the profile of the terrain are either increase, flat or decrease in terms of elevation. The relative configuration of the slope between the profiles will not change unless existing contour line fade out or new contour lines appear. Since the profile of the terrain surface is incorporated with contour lines, a change of elevation on a profile is constant (depends on the contour interval)[3].

CONCLUSIONS

An examination of the results on the sample data sets from the recognition process indicates that the recognition using the HSI component system gave the best result. However, some errors remain in the linework. Most noticeable are the several breaks in the lines and erroneous connections between contours.

The manual work of correcting the recognized contour lines after the color separation process was reduced by the automated tracing and linking process which connected broken contour lines to an amount of about 85%. The other 15% were mislinkings and unlinkings of broken contour lines. In the recognition process, there were some erroneous connections between contours and some map symbols which had the same color as the contour lines and therefore also were picked up. This points out the necessity of an interactive editing facility. Then, as more recognized contour lines were completed, less manual correction of the data sets will be necessary. Further research is needed for reducing this manual work.

In the automated height assignment process, the RCD method showed better results than the Contour Following method[3] in reducing the manual work as well as the CPU time, except on flat areas. However the RCD method increased the total processing time gradually according to the steepness of the terrain.

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Fig.3 Input data (color image)

Fig.4 Color separation's result