AUTOMATING THE PROCESS OF SOIL MAPS CONSTRUCTION

Valentina V. Konakh, Antonina A. Topaz
Faculty of Applied Mathematics and Informatics, Belarus State University
Skorina avenue, 4, Minsk, 220050, Republic of Belarus
(017) 226-55-40; Konakh@fpm.bsu.unibel.by

Abstract – The paper deals with a construction of soil maps on the basis of aerial photographs in the interactive mode with the attraction of the experience of decoders.

1. INTRODUCTION

During soil decoding the main problem is in specifying boundaries of soil contours and determining their genetic belonging with the help of decoding signs. Direct and indirect decoding signs are recognized. The direct signs are hue, size, form and drawing of the photoimage representing separate features of the soil layer. The indirect signs deal with vegetation, geological structure of the terrain, results of economic activities of the man. The indirect decoding signs allow to judge, by the first-hand determined signs peculiar to some objects, the existence of other objects and phenomena.

2. GENERAL PROBLEM STATEMENT

The aim of the research is the development of procedures for soil maps construction (using materials of aerocosmic photography) and the technology for the construction of automated systems realizing the given problem.

The variety of approaches to computer decoding and cartography of soils can be divided into three groups [1].

Visual-computer approaches. In the framework of these approaches visual decoding of soils is carried out. Then the results are digitized and used for computer generation of soil and derived maps.

Interactive-computer approaches, when remote sensing materials are entered into the computer, corrected and segmented. Then the obtained results are visually interpreted by the soil scientist-decoder and only after that a computer variant of soil maps is made. This approach is characterized by high precision of automated segmentation of images, mathematical and statistical conditionality of soil area boundaries. But, unfortunately, this conditionality does not always mean soil-geographic reality of the obtained boundaries.

Approaches of complete automation of soil decoding and cartography. Segmentation of an image is carried out not only on the basis of computer analysis of representative properties of photographs but on the basis of formalization of the experience of visual decoding of soils by soil scientist-decoder as well. This direction is the most promising one. Here an attempt is made to automate separation of soil-geographic contours. With automated decoding, on the one hand, use is made of a large range of possibilities of the modern computer technology for image processing (mathematical, logical, statistical operations on separate images or their series, analysis of the topology of soil areas and use of techniques of mathematical generalization, etc.), on the other hand, an attempt is made to attract the totality of experience accumulated by soil scientists during visual decoding of soils. The main disadvantages of this approach lie in the fact that the problem of complete formalization of decoding signs of soils has not been solved at the present time. The result is that reliable automatic decoding of soils can only be made under «ideal» conditions, i.e. specified conditions of photography, availability of exact information about the state of the earth surface during photography, determined quantitative interrelations of direct and indirect signs with properties of soils, etc.

The paper deals with a construction of soil maps on the basis of aerial photographs in the interactive mode with the attraction of the experience of decoders.

3. MATHEMATICAL MEANS

The solution of the stated problem in the automated system can be divided into the following stages: preliminary image processing with the aim to eliminate errors and noise and to increase the quality, separation of objects in the image corresponding to themes of decoding, classification of the seperated objects.

In the present problem the objects of decoding are homogeneous areas in the image. By classification is meant assignment of separated territories in the photograph to a soil. At the stage of classification use is made of knowledge of an expert. This helps to determine types of soils and to formalize features of classes. Training samples are used for formal specification of classes.

The initial digitized half-hue image of MxN dimension can be presented as a matrix $I = I(x, y)$, elements of which are values from the interval $[0..255]$, $0 \le x < M, 0 \le y < N$.

At the stage of preprocessing use is made of histogram transformations and various methods of filtering. The particular methods are determined by the type of the initial image and the problem under solution.

Histogram transformations consist in changing image elements of one brightness to image elements of another brightness. In principle, a histogram transformation is given by the representation $I' = f(I(x, y))$, where $f(t)$ is an integer function of an integer argument taking values from the interval $[0..255]$, $t \in [0..255]$.

With the help of such transformations, firstly, it is possible to eliminate errors introduced at the stages of photography and scanning correlated with unadequate transmission of brightness for various regions of brightness and, secondly, to improve visual perception, to conceal unnecessary information, to underline the existing difference between objects, to change brightness, contrast of the image. In this case regions of brightness are selected within which the necessary objects fall. These regions are reflected in other ones, as a rule, in wider regions. Shades of brightness that have not fallen within the ranges are suppressed.

Thus the function

$$f_1(t) = \begin{cases} 0, t < a \\ \lfloor ct + d \rfloor, a \le t \le 255 - b \\ 255, t > 255 - b \end{cases},$$

where $a, b \in \mathrm{Z}$, $0 \le a, b < 255$, $a + b < 255$, $c = \dfrac{255}{255 - a - b}$, $d = -ca$, can be used for increasing contrast of separate image elements, for eliminating errors introduced while printing the photograph and scanning when the whole region of brightness [0..255] is reflected in the interval [α..255-b].

Under the influence of the function

$$f_2(t) = \left\lfloor 255 \cdot \left(\frac{t}{255}\right)^{\alpha} \right\rfloor, \text{ где } \alpha > 0, \alpha \in R$$

non-linear distortions of brightness characteristic for certain types of photofilms are eliminated.

Methods of filtering allow to eliminate noise of different kind, to increase image contrast, to underline boundaries of homogeneous areas, to smooth the image, to blur it, etc. Because the present problem deals with area-type objects it is topical to eliminate in the image small objects and noise consisting in sharp local jumps of brightness.

One of the algorithms is based on imposing restrictions on the value of brightness of an image element. These restrictions take into account the average value of brightness in a certain environment of the element under study. The value of brightness at each point of the resultant image should not deviate from the average value of brightness in the environment of the point for more than the given value.

Let $S(x_0, y_0) = \sum_{\substack{0<(x-x_0)^2+(y-y_0)^2\le r \\ 0\le x\le M,\ 0\le y\le N}} I(x,y)$ be an integer function of integer arguments x, y determining the total value of brightness in r-environment of the point (x_0, y_0).

The function $C(x_0, y_0) = \sum_{0<(x-x_0)^2+(y-y_0)^2\le r} Inside(x,y)$, where

$Inside(x_0, y_0) = \begin{cases} 1, & 0 \le x < M,\ 0 \le y < N \\ 0, & else \end{cases}$ specifies the number of an image with integer coordinates that fall within r - environment of the point (x_0, y_0).

Then the function $M(x_0, y_0) = \left\lfloor \frac{S(x_0, y_0)}{C(x_0, y_0)} \right\rfloor$ specifies the average value of brightness for r - environment of the point (x_0, y_0).

To calculate the value of brightness of the element $I'(x,y)$ the average value of brightness $M(x,y)$ in r - environment of the element $I(x,y)$ is calculated. If brightness for an element of the initial image does not fall within $[M(x,y)-\Delta, M(x,y)+\Delta]$, then the value of the corresponding element $I'(x,y)$ in the resultant image is assumed to be equal $M(x,y)-\Delta$ or $M(x,y)+\Delta$ depending on whether the allowable deviation is exceeded or minimized. Otherwise, the value of the element remains as before.

Segmentation consists in dividing the image into areas (segments) according to a certain criterion.

To solve the problem techniques of cluster analysis are used.

When applying this approach two main problems should be solved: (a) to build a formal definition of classes and (b) to determine the degree of belonging of an image element to each class.

It is assumed that the number of classes, corresponding to various types of homogeneous areas, equals n. At the output «a map of areas» $V = V(x, y)$ should be obtained, where V represents a matrix each element $V(x_0, y_0)$ of which specifies the number of the class to which the image element $I(x_0, y_0)$ has been assigned.

Classes are specified by precedence, i.e. by enumerating a certain number of samples for each class [2]. Let $K_1, K_2, ..., K_n$ be classes determining various types of homogeneous areas. Then each class K_i will be formally determined by sets $\Omega_1, \Omega_2, ..., \Omega_l$, that specify samples for the given class of the image I.

When analyzing the degree of belonging of an element $I(x_0, y_0)$ of the image I to a class Ki use is made of the r–environment of this element $\Omega_{(x_0,y_0)} = \{(x, y)|0 \le x < N, 0 \le y < M, (x - x_0)^2 + (y - y_0)^2 \le r^2\}$.

The degree of belonging of an image element (x_0, y_0) to a class K_i is calculated as a maximum among degrees of likeness of the area that is a r-environment of the element (x_0, y_0) with samples specifying the classes.

Let's introduce the following auxiliary function $F(t, \Omega)$: $F(t, \Omega) = \frac{\sum_{(x,y)\in B(t,\Omega)} I(x, y)}{\|\Omega\|}$, where Ω specifies the area, being a sample or r-environment of the image element under study, $B(t, \Omega) = \{(x, y) \in \Omega \mid I(x, y) \le t\}$. This function resembles a function of random value distribution. Such function does not decrease at the interval $[0..255]$ and it changes its value from 0 to 1. Sharp jumps fall within the level of brightness and are highly represented in r-environment of the point (x_0, y_0).

To determine the degree of likeness of two areas use is made of the following function $\mu(\Omega_1,\Omega_2) = 255 - \int_0^{255} |F(t,\Omega_1) - F(t,\Omega_2)| dt$.

The degree of belonging of an image element $I(x_0, y_0)$ to a class K_i is determined in the following manner: $\sigma = \max_{1 \le i \le l} \{\mu(\Omega_i, \Omega_{(x_0,y_0)})\}$, where $\mu(\Omega_1,\Omega_2)$ specifies the degree of likeness between two image areas. The obtained value σ changes from 0 to 255, 0 corresponds to the minimal degree of areas likeness, 255 corresponds to the maximal degree of likeness.

If for an image element $I(x_0, y_0)$ it occured that degrees of belonging for all classes are rather small, then the element in this case should be assigned to a special, the so-called 0-class.

For each class experiments are used to determine a value Δ_k which is a maximum possible degree of likeness when an image element can still be assigned to the given class. A particular case is assignment of the same threshold for all classes.

4. CONCLUSION

The developed technology of soil maps construction has been tested, as an example, on the territory formed on glaciofluvial soil-forming rocks. The processing resulted in the construction of theme maps and calculation of morphometric features of soil layer structure: area, coefficients of separation, inhomogeneity, indices of fraction, complexity.

REFERENCES

1. *Simakov S., Savin I.Yu. Usage of Materials of Aerial and Cosmic Photography in Soil Cartography: Ways of Advancement, State, Problems. - Soil Analysis, №11, 1998. - P.1339-1347.*
2. *Krasnoproshin V.V., Obraztsov V.A. Recognition with Training as a Choice Problem. // Digital Image Processing. - Minsk, RB NAS, № 2, 1998.*