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TEXTUAL MODEL OF GRAPHIC DATA

Abstrakt. *This paper presents a new, textual model of image geoinformation. This model can be applied to the digital photogrammetry and GIS. Black-and-white and color digital images are conversed into a text by means of an alphabet, context-free grammars, and a language belonging to the image languages class; all specially developed for this purpose. Geometrical properties of terrain objects are analysed with a distinct mathematical device. An important aspect of this textual model is that the generated text is a semantic network. Thus, lexicomorphologic, lexicologic and lexicographic methods of mathematical linguistics can be applied to the computer recognition of terrain objects and to the analysis of their properties. Examples of graphic data in the textual model are presented.*

KEY WORDS: Photogrammetry, GIS, Data Mining, Data Structures, Analysis, Transformation

Introduction

Present research aimed to develop new structures of graphic and semantic GIS bases as well as modernise geoinformation technologies. The increasing number of GIS users points at the necessity of reassessing the efficiency of the existing geoinformation technologies and creating new technologies based on new ideas and methods (Shneiderman, 1984). The textual model of image geoinformation offers such a possibility as it can be effectively used in GIS as well as in raster or vector models. The results of the present research on conversion of black-and-white and colour raster images into a textual model (with the formal grammar methods) are demonstrated below. The conversion was completed with the use of raster images meeting Rosenfeld requirements (Rosenfeld, 1969).

1. Textual model: basic concepts

For the textual model of image geoinformation the following concepts are defined: the alphabet, the letter, the word, the offer, the grammar and the language. In particular it is accepted, that the alphabet **(V)** is the limited set of symbols:

$$(\mathrm{V}) = \{s \mid s \in \{s_1, s_2, s_3, \ldots, s_K\}\} \quad (1)$$

where
k = dimension of the alphabet.

The letter (a) is any symbol of the alphabet **(V)**, if *(a)* $\in$ **(V)**.

Let **(V)** be the alphabet that can be generated from symbols of any code table. The code table K can be of any dimension, for example, it could be of 8, 16, 28, 32, 64, 128, 256, which helps to determine the set of the alphabet symbols as well as dimension k of the alphabet. Generally, $k \neq K$.

Six special symbols s^* will additionally be introduced:

∅ = symbol for a designation of an empty word
& = symbol - separator of words
Ξ = symbol - separator of the offers
□ = symbol-identifier of the black-and-white image with two levels of spectral clearness
ϒ = symbol-identifier of the black-and-white image with 256 levels of spectral clearness
⊗ = symbol-identifier of a color image in the standard RGB.

Combinatorial context-free grammar ***G*** will be defined as

$$G = ((V), V', P, S_0), \qquad (2)$$

where
(V) = basic alphabet
V′ = auxiliary alphabet, which includes the initial raster image and special symbols
P = rule of substitution
S_0 = initial symbol. It is supposed, what $S_0 \in V'$.

The language defined by grammar **G** is represented by ***L(G)***. It is possible to make words out of the alphabet symbols by using the rules of substitution:

$$S = \{s_j / l \in U\}, \qquad (3)$$

where
S = word
s_j = symbol of the alphabet with an index j
U = index set: U = $\{l \;/\; l = 1,2,3,\dots, k\}$
k = dimension of the alphabet.

2. ZA-grammar (G[1])

These are the main definitions of **ZA**-grammar (**G[1]**) above **(V)** and V′ for the conversion of black-and-white digital images with two levels of spectral clearness into a textual model.

Definition 2.1. The alphabet dimension k is equal to or smaller than the amount of pixels in a line of a raster: $k \leq m$

Definition 2.2. If condition *(a)* ∈ **(V)** is satisfied, and $S \neq S_0$, then S is a word in ***L*(G[1])**, otherwise $S = \varnothing$ and the language will be empty.

Definition 2.3. For the first line of a raster, the symbol-identifier of the initial raster image as well as an empty word are both the initial meaning of word *S*. For example, for a black-and-white raster image (fig. 1a) the initial word will be defined as $S=\square\varnothing$.

Definition 2.4. Rule of substitution P is a function of substitution (the function of formatting a word):

$$S \Rightarrow S + s_j = \left\{ \frac{s_j \Leftarrow (C^* \neq C_F)}{Null \Leftarrow (C^* = C_F)} \right\} \qquad (4)$$

where

S = a word

$C^* = \{C_{i,j} / j \in U\}$

Null = empty operation

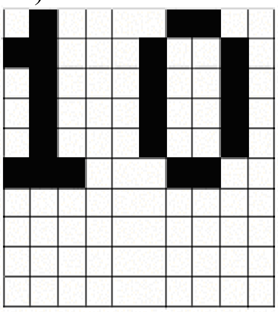
$i = 1,2, \ldots, n;$

$j = 1,2, \ldots, k.$

If $k = m$, the offer will consist only of one word, and the amount of offers in the text will be equal to n. If the alphabet dimensions $k \le m$, one line of the raster may serve to construct the offer of t words:

$$t = \text{int}\,((m-k)/k)+1 \qquad (5)$$

a)



b)

1	0	1	1	1	1	0	0	1	1
0	0	1	1	1	0	1	1	0	1
1	0	1	1	1	0	1	1	0	1
1	0	1	1	1	0	1	1	0	1
1	0	1	1	1	0	1	1	0	1
0	0	0	1	1	1	0	0	1	1
1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1

Fig 1. Black-and-white digital image as: a). an image, b). a matrix

The language based on **ZA**-grammar belongs to the class of image languages (Rosenfeld, 1969). Let a black-and-white digital image (fig. 1) be given, in which numbers 0 and 1 correspond to the spectral clearness levels of the black and of the white colours respectively. The colour of the background can be freely chosen, in this case it is white: $C_F = 1$.

Let alphabet **(V)** = {*a,b,c,d,e,f,g,h,i,j*}be set and an image (fig. 1b) be converted in accordance with **ZA**-grammar. The resulting image in the textual form will be recorded as:

□*bgh*&Ξ*abfi*&Ξ*bfi*&Ξ *bfi*&Ξ *bfi*&Ξ*abcgh*&Ξ∅&Ξ∅&Ξ∅&Ξ∅&Ξ (6)

ZA-grammar can also be used for the conversion of black-and-white achromatic and colour raster images into a textual form.

3. AZ-grammar (G^2)

Present research demonstrates that the image in the textual form based on **ZA-**grammar are most effectively applied to the analysis of geometrical properties of objects. For the automatic photointerpretation of objects, it is more rational to use textual images based on **AZ-**grammar**(G^2)**. Black-and-white achromatic and colour digital images are initially used for generation of a textual model. The alphabet dimension k is set with regard to the number of levels of spectral clearness quantumisation of an achromatic digital image (which usually equals 256).

Definition 3.1. Let function of substitution P (the rule of a word construction) be formulated as follows - for each i - pixel and j - line of the raster:

$$
\begin{aligned}
&C^* = \{C_{i,j} \mid j \in U\};\\
&L = C^*;\\
&S \Rightarrow S + s_j = \{s_j \mid l \in U\} \qquad (7)\\
&j = 0, 1, \ldots, m;\\
&i = 0, 1, \ldots, n.
\end{aligned}
$$

If $m \le 256$, the offer will consist of one word, and the number of offers in the text will equal n. If $m > 256$, it is possible to construct an offer out of one line of the raster. The offer will consist of t - words and the number can be calculated with formula (5).

Let the alphabet be the Windows code table number 1052. Figure 2 demonstrates a part of a digital black-and-white image with 256 shades of the grey colour.

102	108	114 121	108	108	109	110	112	108
106	101	114 97	99	109	110	108	121	122
108	104	110 98	100	119	104	120	121	121
110	106	102 122	121	108	119	120	117	115
112	107	109 122	116	110	120	119	113	114
111	110	110 115	116	116	120	120	118	117

Fig. 2. A part of a black-and-white digital image with 256 shades of the grey colour

This digital image will be converted by AZ-grammar (G^2) into a textual form as:

ϒ∅*flryllmnpl*&Ξ*jeracmnlyz*&Ξ*lhnbdwhxyy*&Ξ*njfzylwxus*&Ξ*pkmztnxwqr*&Ξ*onnsttxxvu*&Ξ (8)

The generated text is a semantic network (Horn B., Minsky M.. Shirai Y, Waltz D., Winston P.H. (ed.), 1975), thus lexicomorphologic, lexicological and lexicographic methods of mathematical linguistics can effectively be applied to the computer photointerpretation of terrain objects and to the analysis of their properties.

Definition 3.2. One and only one letter of a given alphabet will correspond to each level of the spectral clearness in a digital image.

Consequence 1. According to definitions 3.1 and 3.2 any digital image can be transformed into a textual form. The opposite is also true, i.e., any text written in a natural language with the use of alphabet **(V)** can be transformed into a black-and-white or colour digital image with shades of a colour corresponding to the alphabet dimensions. The resulting image can be recorded as a matrix *C*, whose each element $c_{i,j}$ will correspond to value of the spectral clearness level D_l. For example, such a function can be defined as follows: for each symbol of the text $s_{i,j}$ the generation of a digital image is carried out according to the formula:

$$c_{i,j} = D_l \qquad (9)$$

where

i = number of the offer in the text

j = number of the letter in the offer

$i = 0,1,2, \ldots, m$;

$j = 0,1,2, \ldots, n$;

m = amount of the offers in the initial text and dimension of a raster on an axis X

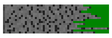
n = amount of symbols in the offer of maximal length and dimension of a raster on an axis Y

l = serial number of the letter in the alphabet.

For example, Shakespeare’s sonnet CXIX:

What potions have I drunk of Siren tears
Distilled from limbecks foul as hell within,
Applying fears to hopes and hopes to fears
Still loosing when I saw myself to win!
… … … … … … … … … … … … …
And gain by ill thrice more than I have spent.

If the Windows code table 1052 and Windows standard palette is used, the text will be transformed into a digital image shown in fig. 3.

a). 

b).

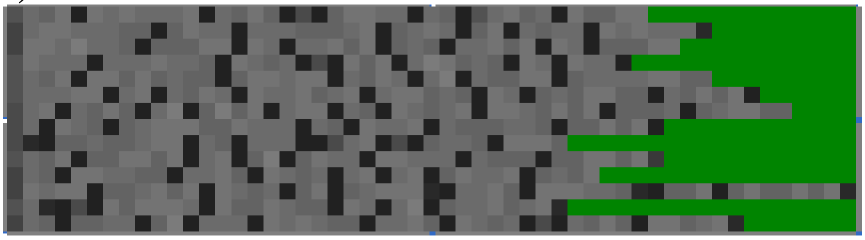


Fig 3. Shakespeare's sonnet CXIX in a graphic representation (a - in scale 1:1, b- enlarged 8 times)

For the best comparison of the text and its graphic representation the ends of the offers are marked with the green colour. Consequence 1 and the above example clearly demonstrate that any textual information stored in a GIS database can be transformed into the graphic form and fitted in a cartographical image. It is possible therefore to exclude semantic databases from the geoinformation technology.

CONCLUSION

This paper presents theoretical and practical aspects of geoinformation technologies in GIS as transition of graphic data into the textual model. Present research demonstrates how to transform black-and-white and colour digital images into the image in the textual form, basing on a chosen alphabet and two types of grammar. Importantly, the textual model can be effectively applied to the GIS and digital photogrammetry.

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